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An Investigation into the Use of Ethnography and Participatory Design in Identifying and Meeting Collaborative Needs
A Case Study of Software Development Teams at Airbus

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An Investigation into the Use of Ethnography and Participatory Design in Identifying and Meeting Collaborative Needs: A Case Study of Software Development Teams at Airbus

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Abstract

This thesis presents an ethnographic process for identifying the needs and requirements for collaborative support tools within an organisation, and a participatory design method for matching these to existing off the shelf technologies. This process is developed through, and illustrated with a case study looking at tools to support collaborative software development teams at Airbus. The thesis begins by exploring the background to systems development processes as well as methods for identifying needs and understanding the context of use. It then presents an in depth description of ethnographic studies carried out at Airbus in which the needs of software development teams are identified, along with high-level requirements. These focus on ways to aid traceability of design rationale in a lightweight and flexible manner. A description of the process used to develop a participatory design workshop that sought to bridge the gap between the output of the ethnographic work and the selection of potential solutions is provided. This includes three pilot studies used to refine the method and a final workshop held with stakeholders at Airbus. The thesis then describes the evaluation of two potential solutions, the Livescribe Echo Smartpen and a Motorola Xoom tablet computer with a number of apps installed. Through evaluations it was possible to identify the Smartpen as being the most feasible technology, although some barriers to use still existed. Finally the thesis concludes with a summary of the process developed, reflections on the methods used, and an outline of the case study. Limitations and recommendations for the future are also outlined.

Chapter 1

Introduction

1.1 Background

This thesis discusses a process for identifying needs and requirements for collaborative support within an organisation. It also describes a method for involving stakeholders in matching these requirements to existing off-the-shelf technology. This work was based around an industrial case study of tools to support collaborative software development teams at Airbus.

Technology and tools are ubiquitous in human life, especially in the workplace. Within the fields of Human Factors, Computing, and more recently Human Computer Interaction (HCI), the development and introduction of technology has been studied extensively to try and increase the likelihood of effective and successful results. It is now generally recognised that methods for studying context and involving users are vital to making this successful. Previous research has predominantly focused on processes for developing new software, which can be time consuming and expensive. Conversely, this thesis takes the stance that due to the ever-increasing amount of novel hardware and software becoming commercially available, methods should be investigated to look at how this can be fitted to the needs of a particular setting, whilst still recognising the value of contextual understanding and stakeholder involvement. This is particularly relevant for tools that support collaboration where needs may be less complex, such as providing greater awareness, or aiding communication, but still affected by the specific context of an organisation.

Today debate still exists over the best ways to achieve contextual understanding, and there are continuing concerns over the way in which the understanding of context can be effectively made use of in the design process. This thesis will contribute to this by discussing a process for studying a domain and context in depth, and the way in which this was used to establish support 'needs' and high-level requirements for technological interventions. These requirements were then fed into a design workshop that encouraged stakeholders to envision future work practices that utilised existing technology to meet these needs.

In summary, this thesis describes a process for identifying the 'needs' of collaborative teams in industry along with high-level system requirements. A technique for working with stakeholders to match these needs to existing technology is also discussed. A case study of multi-disciplinary software development teams formed the focus for this research.

1.1.1 Existing Technology

Today there are many off-the-shelf technological solutions available and it can be extremely difficult for people and companies to be aware of the opportunities and limitations (or even the existence) of all of these. Instead companies often 'make do' with well-known off-the-shelf solutions, or develop their own in house tools. A brief search on the Internet for 'collaborative tools' will provide an overwhelming number of possibilities. Thus, a process for aiding in this choice may be beneficial, and could prevent companies from wasting time and money on developing their own technology unnecessarily, or introducing the wrong solution. It is important to involve stakeholders in this process as they can provide valuable input from their work experiences. However, they may not be aware of the technology that exists, and thus a method is needed for exposing them to potential technological solutions whilst looking at the ways in which this could support the identified needs and requirements.

1.1.2 The Setting

This research was carried out in partnership with Airbus UK, a large aircraft manufacturer. An extended period of time was spent working within the Aerodynamics Group where aircraft wings are designed by a group of engineers. The Aerodynamic design process involves the use of a large number of extremely specialist software tools for setting up models of wings, running computational air flow simulations, and analysing the results. The group works closely with an external team of software developers to create these bespoke software systems. This is a complex and highly involved process, requiring close collaboration between software developers (who have the computing knowledge), aerodynamic engineers (who possess the domain knowledge), and managers (who are concerned with budgets and deadlines).

This research provides a case study of these multi-disciplinary design teams, where their collaborative support needs were established through ethnographic work before the identification and evaluation of potential support technologies. The work eventually focused on supporting collaboration in the software development teams through the provision of tools to assist the capture and sharing of design rationale.

1.1.3 Research Questions

This thesis attempted to address a number of questions surrounding the identification of needs for support and how these can be matched with existing technology. A case study of software development teams at Airbus formed the context for this. The central research questions are:

Q1. What methods and processes can be used in an industrial setting to identify areas for support in collaborative work?

Q2. How can stakeholders be effectively involved in identifying which existing technology could meet these needs?

Q3. Case Study: What are the collaborative needs of the software development teams at Airbus and which technology can best support these?

The development of these questions will be discussed in more detail in Chapter 2.

1.1.4 Research Methodology

This research is formed around a case study of collaboration in software development teams. Ethnography has been used along with other qualitative methods to help understand the richness and depth of this case study. Ethnography is an approach to understanding contexts that involves long term, immersive studies, combining both fieldwork and participation (Dourish, 2006). It was initially used by anthropologists but has become a common tool for studying context within the domain of computing. As this research has involved an extended period of immersion within the domain at Airbus, it was an ideal approach to use. It allowed for an in depth case study of the domain to be gathered, whilst also becoming a vital method in the design process being discussed within this thesis.

The research methodology that drove this research will be discussed in greater detail in Chapter 2.

1.1.5 Research Output

The output of this research is a proposed method for identifying technology to support collaboration in software development teams. This process is summarised in Figure 1. A summary of the stages in this process is as follows:

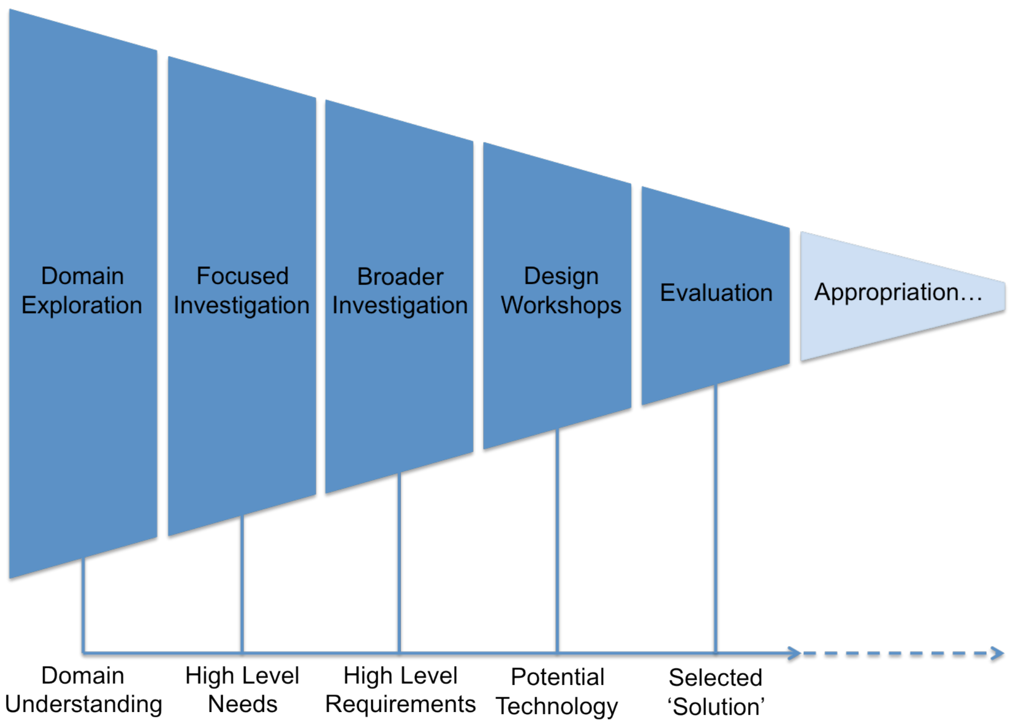

Figure 1 - A Process for Identifying Collaborative Support Needs and Exploring Existing Technology as a Potential Solution

Domain Exploration

This stage of the research examined methods for gaining familiarity with a complex domain (specifically aerodynamic design and the development of software to support this). It primarily involved taking an ethnographic approach, spending time immersed in the domain, and carrying out informal discussions.
Output: An improved domain understanding that aided the future phases of the research process.

Focused Investigation

This stage examined methods for investigating collaboration within the domain, especially utilising a case study approach for understanding the work within a software development project.
Output: Identification of the case study focus (collaboration in software development) and the high-level needs of the development teams.

Broader Investigation

Having identified high level needs it was necessary to investigate these more broadly across a wider range of projects and locations in an attempt to triangulate the findings. This also allowed further issues to be probed in greater detail. This stage utilised surveys and interviews for data collection.
Output: A set of high-level requirements for potential support.

Design Workshop

This stage of the process involved the development of a method for matching existing technology to the needs and requirements that had been identified. This involved a scenario based participatory design workshop that presented future visions and existing technology as inspiration sources. The method was refined through pilot workshops with PhD and EngD students before a final workshop was held at Airbus.
Output: Through analysis of the workshop outputs it was possible to identify further requirements and two candidate technologies for further investigation. These technologies were the Echo Livescribe Smartpen and Motorola Xoom tablet.

Evaluation

This phase involved the two technologies being deployed within the field with two potential users. Interviews were used to gather feedback on this use in order to evaluate the comparative success of the technologies.
Output: A favoured technological solution (the Smartpen) and reflections on some remaining barriers to use.

Appropriation

This stage is not investigated in this thesis but is an important consideration when implementing technology and thus should still be considered when considering the introduction of technology into a workplace.

1.1.6 Research Contributions

A Process for Identifying Collaborative Support Needs and Exploring Existing Technology as a Potential Solution

This thesis discusses an approach for carrying out ethnographic investigations to establish needs and high-level requirements of collaborative teams in industry with the aim of meeting these with existing technology. This contributes to the already extensive knowledge on the uses of ethnography in design within the field of HCI. The focus on meeting these with existing technology steps away from the more common use of informing the design of new technology.

Technology Inspiration Workshops

A process for carrying out 'Technology Inspiration Workshops' with stakeholders is also presented. Descriptions of this process when carried out with students and software development stakeholders are presented and this is of interest to researchers within the fields of Participatory Design and CoDesign. The particular focus on the workshop as a follow on from ethnographic work is a novel application of the method. In addition to this, as a participatory process for introducing stakeholders to existing technology, it should be of interest to anyone looking at methods for introducing technology in the workplace.

A Case Study of Collaborative Software Development Teams

The thesis also presents a case study of collaborative software development teams at Airbus. Whilst collaboration within software development teams is an area that has been studied in depth in the past (although not in this particular context) it is still an area of great interest as development processes continue to evolve. The case study particularly focuses on tools to aid traceability of decisions and the rationale behind them. A solution in the form of lightweight, but flexible tools (such as the Echo Livescribe Smartpen and Motorola Xoom tablet) is a novel approach and the results of the evaluations will contribute towards further research into this area.

Reflections on Applications of Methods in Industry

Finally through this case study, it is possible to reflect on methods for carrying out ethnographic work and design workshops within an industrial setting. On a more logistical level the thesis will provide recommendations for dealing with the associated challenges encountered during this, which will be of interest to anyone carrying out similar studies in industry.

1.1.7 Thesis Outline

This thesis explores the outlined problem in a number of stages, with the case study of software development teams at Airbus forming the focus of this. This case study was an exploratory instantiation of the design process and allowed for an in depth reflection on the methods being developed and refined.

The remainder of Chapter 1 will introduce the case study at Airbus to provide an initial insight into the context of this work.

Chapter 2 will provide an overview of the methodological approaches guiding this thesis and a background to the methods used.

Chapter 3 will provide a background to literature and previous research on what 'needs' are and their relationship with technology, as well as methods for studying context and involving users in design. It will also briefly introduce literature linked to the case study of collaboration in software development teams.

Chapters 4 to 6 will present an overview of the ethnographic studies carried out at Airbus and the process in which the case study focus was established along with the needs and high-level requirements of the software development teams. Some time will be spent looking at collaboration within aerodynamic design (rather than specifically in software development teams) as this was an initial area of interest, and also provides vital context to the software development case study. Reflections on the methods used during this work are also included.

Chapter 7 provides a description of the process used to develop a participatory design workshop that sought to bridge the gap between the output of the ethnographic work and the selection of potential solutions. This includes three pilot studies that helped to refine the method, and the final study at Airbus.

Chapter 8 details the evaluation of two potential technological solutions at Airbus. The relative success of these technologies is discussed along with an analysis of how well they met the requirements identified in previous chapters.

Chapter 9 concludes this thesis by summarising the outputs of the research, specifically the process that has been developed, along with the case study findings and reflections on the methods used. The contributions of this work are then discussed, along with the limitations and recommendations for future work.

1.2 Case Study Background

This thesis is based around a case study of collaboration within an industrial setting. The setting in question is Airbus, and more specifically the Aerodynamics Group.

This research initially set out with a broad aim of investigating collaboration within this context as a whole. This included the following areas of interest:

- Collaboration within the ***aerodynamic design*** process
- Collaboration within the ***development of software*** to be used in aerodynamic design.

Throughout the rest of this thesis these areas will be referred to as 'aerodynamic design' and 'software development' respectively.

The following section will provide an introduction to Airbus and the work of the Aerodynamics group, as well as a brief background to the wing design process and methods used in this, both historically and more recently. It will also touch on the software used to support the design process. More detail will be added during later chapters; where the findings from this case study will be explored in depth.

1.2.1 Company Background

Airbus is a multinational aircraft design and manufacturing company. It was founded in 1967 when the French, German and British governments announced plans to build a European aircraft (to become the A300). Today it has sites across the world, including the headquarters in Toulouse France, and further European sites in Spain, the UK, Germany, and Russia. This research has been carried out within the Aerodynamics Group based in Filton in the UK which is a Centre of Excellence for Wings, and where the design of the wings is carried out (Airbus, 2013).

In its history Airbus has developed and manufactured a number of well-known aircraft such as the single aisle A320, the best-selling aircraft product line of all time (Airbus, 2013), and the A380 (see Figure 2), the world's largest commercial aircraft (Airbus, 2013).

Figure 2 - Airbus A380

1.2.2 CFMS

This research was carried out as part of the CFMS initiative. CFMS (the letters no longer stand for anything) is a 'not for profit' company set up between a number of engineering firms including Rolls Royce, BAE Systems, MBDA, Williams F1, and Airbus (where this work was based).

The company has a number of visions for the future across areas such as simulation, computer infrastructure, and design process efficiency. An improvement in System Interfaces is also a key part of this vision. A number of interconnected research projects form part of CFMS, this research being one of them.

A number of projects are looking at specific engineering issues such as optimisation methods and ways to achieve the desired form of airflow across wings. This project was initially concerned with improving system interfaces at Airbus, a key component of the CFMS vision. However, the scope was very broad and over time it moved towards looking more specifically at tools for supporting collaboration in software development teams at Airbus, which should subsequently improve the quality of the systems being developed.

1.2.3 Aerodynamic Design

This work has involved studying the Aerodynamic Design Group at Airbus. This group is responsible for designing wings to achieve optimal airflows around them. The process of aerodynamic design has changed dramatically over the years, and continues to do so.

History

As Shevell (1989) details, a number of different design approaches were used by the pioneers of aviation. This ranged from early 'wind tunnel' testing such as the whirling arm test rig developed by Sir George Cayley, which measured forces on airfoils, to full sized working prototypes as developed by Lilienthal (but that resulted in his death during a test flight).

The Wright brothers used a combination of these techniques, taking a methodological, rational and persistent approach to development. This included a box kite prototype, a comparison of potential designs by rigging them to a bicycle, wind tunnel testing of over 200 model wings, and finally full scale working models.

Current Status

Today the process of designing aircraft is much more technically robust. Firstly, continued development of wind tunnel technology has made it possible for small-scale prototypes to be accurately tested for their aerodynamic properties prior to building and flying the plane.

In addition to this, increases in the processing power of computers has led to the ability to simulate the flow of air around a plane mathematically without the need for physical models. As a result of this development, simulations on computer models of wings now form the basis of the initial wing design process. This computer simulation technology is known as Computational Fluid Dynamics (CFD).

CFD forms a prominent role in the Aerodynamic Design process at Airbus, yet this is just a small part of a much larger wing design process.

Design Process in Industry

The initial criteria for a new wing are set out during the conceptual design process, where the key customer requirements such as cost, performance, and capacity are addressed and a basic aircraft configuration decided upon. The target of the aerodynamics team is to meet these performance requirements within the design of the wings, given the constraints that come with it, such as the ability to carry a fuselage of a certain size. Examples of additional constraints are that the wing construction has to be feasible given the materials being used, and the fact that the wing has to be able to contain fuel tanks and high lift devices (see Figure 3). In addition to this, the engines are mounted onto the wing, also influencing its design.

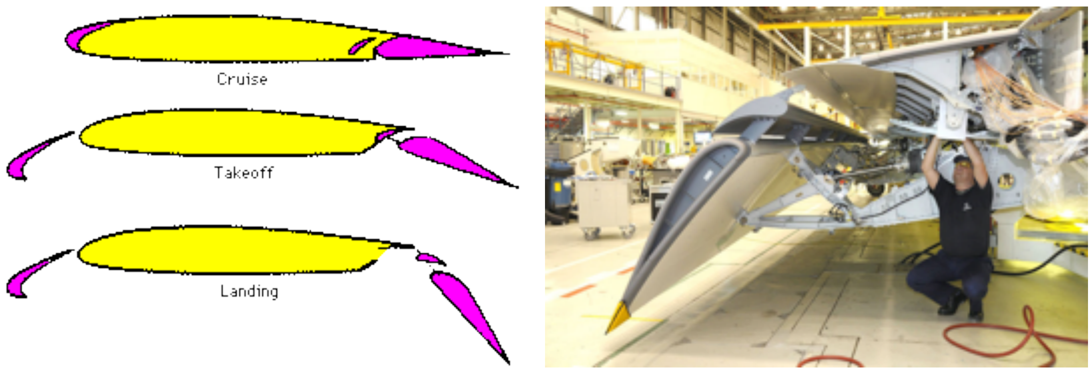

Figure 3 - High Lift Devices

This trade-off and optimisation means that the design process is not a simple linear process. In fact there are a number of concurrent streams of work being carried out at once, as different specialist teams work on different aspects of the design, before communicating progress at set intervals.

Within the department being studied, a number of specialist groups work together on specific aspects of the design process, such as wing shape and high lift devices, whilst other groups specialise in providing design data to other groups to contribute to the collaborative design of the aircraft as a whole.

CFD Based Design

In addition to this complex design process, the CFD based design work is a technical challenge in itself. This is because, when carrying out CFD, it is not simply the case of pressing a button and waiting for results to be displayed on the screen. The process required to set up a CFD job involves a number of steps and the particular process depends on the CFD program that is being used (and these vary depending on the stage of design).

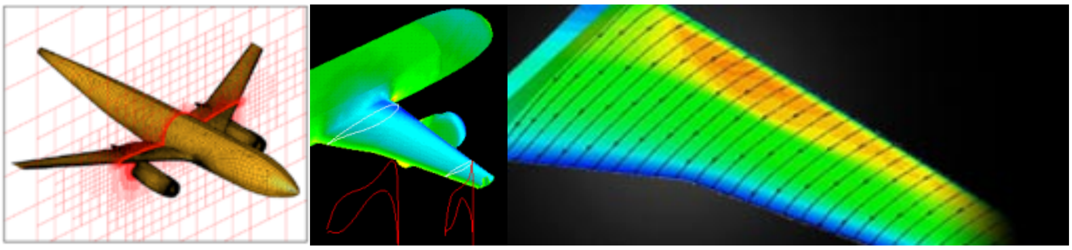

Figure 4 - Traditional Views of CFD Based Design

In general, CFD preparation involves defining the 3D (or 2D) model that the airflow calculations will be based on. This stage is known as geometry preparation, or CAD definition. The next stage then involves setting up the space around the model i.e. the properties of the air around the wing and the surface of the model itself, as this is crucial to the calculations. This process is known as mesh generation.

Once this mesh is set up, the CFD analysis can be carried out. This requires certain parameters to be set, such as the air viscosity, angle of attack, and speed for each run. In addition to this, it may be necessary to transfer the files from a local machine to the appropriate supercomputers that have the necessary processing capability to run the simulations. Finally, once the calculations have been completed (this can take minutes, hours, or even days) the results can be retrieved and visualised. Analysis can then be carried out, before repeating the process again in different conditions or with an altered design.

A generic and simple overview of the aerodynamic design process can be seen in Figure 5. By adding this CFD process into the design process as a whole, the picture begins to look quite complex.

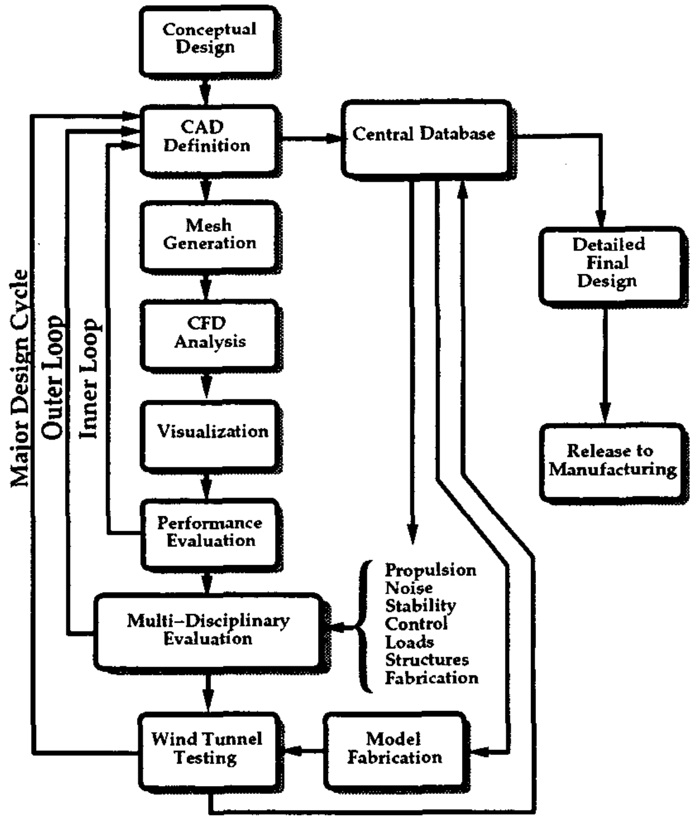

Figure 5 - Typical Aerodynamic Design Process (Jameson, Martinelli, Alonso, Vassberg, & Reuther, 2000)

1.2.4 Software Development

The teams at Airbus use a number of pieces of software to support the aerodynamic design process and these will be introduced later in this thesis. The software supports the CFD process, the representation and sharing of data, and more general tasks such as data storage and retrieval, and communication. The aerodynamic design work is largely dependent on computer technology and due to the complex nature of the work, much of this software is bespoke. Thus software development forms a central part of the work at Airbus, involving close collaboration between developers and engineers.

1.3 Summary

This chapter has provided an introduction to the research questions, a summary of the thesis and its contributions, and a brief introduction to Airbus and the case study. As we have seen, the thesis will present an ethnographic approach to establishing the 'needs' of collaborative software development teams along with participatory design workshops that involve stakeholders in matching these needs to existing technology.

The next chapter will discuss the methodology and methods that were used during this research.

Chapter 2

Methodology

Before detailing the work carried out in the development of this thesis, the following chapter will outline how the research process evolved along with the principles that shaped it.

2.1 Research Overview

The following section will expand upon the initial research overview provided in Chapter 1 to describe the way in which the research process emerged, considering the opportunities and constraints that were encountered.

Initial Proposal

The initial proposal for this research was provided by Airbus who wished to investigate the computer systems and interfaces used by the teams within the Aerodynamics group. A scoping document was provided that outlined the problem space very broadly, and listed a number of potential research topics. These included:

- *The changing role of engineers* – this is occurring due to an increase in available data, information sources and increased computational capacity. How can interface design support this?
- *Collaboration* – modelling the design space at a design process level i.e, the interfaces between the teams (and how this is changing).
- *Innovation* – who should be doing this, how is it maintained and how is it manifested throughout the design process. Can it be supported?
- *Knowledge capture, sharing and re-use* - Integrating the design process with existing KM tools. How can design rationale be captured and re-used across boundaries?
- *Information Overload & Data Visualisation* - Difficulties that arise from an increased access to information i.e. searching for data, filtering and information presentation.
- *General usability issues.*

Narrowing The Scope

Whilst all of these issues were potentially interesting as a topic of research, it was not possible to address all of these within a single thesis. Therefore it was necessary to spend time scoping out the problem space in more detail to determine which of these areas to pursue. This process became a fundamental stage of the research and is discussed in Chapter 4. During this phase, time was spent immersed in the domain in order to gain familiarity and to begin to identify key challenges.

Characterising Collaboration

Through this early work it became clear that collaboration was a central aspect of the work being carried out. This involved the way in which the team members communicated and shared resources within the course of their work. However within the domain of study there were two key areas where collaboration was taking place (and these were not entirely exclusive from one another). These were:

- *Aerodynamic Design* -> collaboration between the engineers designing the wings.
- *Software Development* -> collaboration between stakeholders involved in the design and implementation of software systems used by the aerodynamic engineers.

Having identified that collaboration was a vital but challenging process in both of these domains, it was necessary to explore them in more detail to establish the specific needs that the research could address. This process used a variety of methods that will be discussed in section 2.4. Through this work it was possible to characterise both domains more clearly, especially the high level features of both. These are outlined in Table 1 and were important in determining the feasibility of exploring each of these areas further.

Table 1 - High Level Domain Features

	Aerodynamic Engineering	**Software Development**
Time Scale	Long. Projects continuing over a number of years.	Medium–Short. Projects taking place over months or years.
Processes	Prescribed and well defined.	Flexibility across projects.
Team Distribution	Geographically distributed across Europe.	Geographically distributed across sites in UK and Europe.
Team Size	Large (extending beyond the Aerodynamics Group)	Small (less than 20).
Management	Many levels of hierarchy	Local and less hierarchical

Due to the shorter time scales and greater flexibility within software development, studies of collaboration within this domain were logistically more feasible given the time constraints of the project and the need to recruit participants. Therefore the decision was made to focus on this domain for these reasons combined with the specific details and challenges within the collaboration itself (this is discussed further in Chapter 5).

Collaboration in Software Development

Through further research in the domain of software development it was possible to identify a number of key issues and support requirements (as well as constraints). These will be detailed in Chapter 6. However, at this stage it was still not possible to identify exactly how these requirements should be met with technology. It was felt that further user involvement could assist with this and it was also realised that these needs could be met with existing technology (rather than engaging in a lengthy development process). The needs of the software development teams weren't complex enough to require bespoke tools, and existing commercial technology presented a more robust and reliable solution.

Participatory Design Workshops

In order to gain user involvement in identifying this technology, a Participatory Design method was developed that would introduce this existing technology whilst also involving creative thinking to ensure that the participants were not constrained by their perceptions of existing limitations. This workshop process is described in detail in Chapter 7.

The workshop method was refined through three pilot sessions with PhD and EngD students before a final session was held at Airbus. These pilot workshops were carried out as it was important to gain experience with the method without using up valuable time with Airbus stakeholders. Through analysis of the final workshop it was possible to identify two technologies as potential solutions (although these were not the only potential solutions) and these were deployed and evaluated.

Technology Evaluations

This final stage of the research was constrained by problems with gaining access to participants (this will be discussed later), but studies were eventually carried out with two employees. This allowed a high level overview of the comparative success of the technologies to be gained as well as an evaluation against the requirements. This process is described in Chapter 8.

2.1.1 Summary

The nature of the research described in this thesis evolved over a period of time, and the final research questions reflect the outcome of this. The initial problem space was very broad and it was necessary to break this down over time. It was this process of exploring the problem space, and then finding a potential solution that became one of the primary outputs of this research. This output includes recommendations for a process for establishing needs, and a participatory design workshop method for identifying existing technology to match these. Through this process, a case study of the needs of software development teams was formed, and potential support tools identified.

Subsequently, the research questions explored through this thesis were as follows:

Q1. What methods and processes can be used in an industrial setting to identify areas for support in collaborative work?

Q2. How can stakeholders be effectively involved in identifying which existing technology could meet these needs?

Q3. Case Study: What are the collaborative needs of the software development teams at Airbus and which technology can best support these?

2.2 Research Objectives

Each of these questions can in turn be broken down into a series of objectives and activities that addressed these:

Q1. What methods and processes can be used in an industrial setting to identify areas for support in collaborative work?

- Explore a variety of methods to capture information in the industrial setting being studied.
- Reflect on the success of the methods in identifying the support needs of collaborative teams.
- Reflect on the suitability of the methods within an industrial setting.
- Create a formal list of needs expressed as requirements.

Q2. How can stakeholders be effectively involved in identifying which existing technology could meet these needs?

- Develop a workshop method to expose stakeholders to existing technology and envision ways to support their work with this.
- Identify a means of representing this technology within a workshop.
- Refine the workshop method with a series of pilot workshops.
- Carry out a workshop at Airbus to identify potential technology and evaluate the method.

Q3. Case Study: What are the collaborative needs of the software development teams at Airbus and which technology can best support these?

- Identify the needs of software development teams using a variety of methods.
- Break down the needs into a set of requirements.
- Represent and explore these requirements in a Participatory Design workshop.
- Analyse the workshop output to identify further requirements.
- Identify which technology most effectively meets the requirements identified both before and during the workshop.
- Explore the success of this technology through evaluations of its use in the software development context at Airbus.

2.3 Research Stance

The research stance taken in this thesis has been heavily influenced by a background in Computer Science and particularly experiences in the field of Human Computer Interaction (HCI). HCI is an interdisciplinary subject that looks at the way in which people interact with computers, drawing on knowledge from studies of human cognition, human behaviour, and computer science. Through an MSc in Human Communication and Computing, experience has been built of both qualitative and quantitative methods of research for understanding users, tasks, and contexts of system use.

This research reflects a pragmatic approach, in that the research actions were influenced by the practicalities of a particular situation and the need to remain flexible in the methods used.

The work also sits within the 'third paradigm' of HCI as described by Harrison, Tatar, and Sengers (2007). This 'Phenomenologically-Situated' world-view sees the goal of interaction as supporting situated action and meaning making within specific contexts. This is a common stream of work within HCI and sees researchers asking questions such as 'what existing situated activities should we support', and 'how do users appropriate technologies (and how to support this)?' This research is often supported by research disciplines such as ethnography and ethnomethodology and values the details and complexities of situations.

With a focus on details and complexities, this work is predominantly qualitative, where the emphasis is not on reducing information down to measurements and numbers, but instead on understanding the qualities of technology and how it is used (Adams, Lunt, & Cairns, 2008).

During this research it was not deemed necessary to reduce findings to a set of numbers, as these would have little use in a design context. However at times, the findings are represented numerically to help to characterise the situation. Highly controlled data collection approaches such as experiments were not deemed appropriate for this thesis as they fail to utilise the access to such a rich real life environment. These approaches generally look at questions framed around investigating whether changes in variables will have a significant effect on another (Blandford, Cox, & Cairns, 2008), yet this often requires naturally occurring variability in the environment to be controlled. This approach was not pursued within this research due to the desire to understand the true nature of the context for the purpose of design.

2.3.1 Unit of Analysis

As guided by the phenomenologically-situated and qualitative stance of this research, the unit of analysis was broad. The focus of study was the context of work, especially collaboration within this. Whilst the smaller details of this weren't ignored, details such as button clicks when using computer interfaces were not the primary unit of analysis. This research looks at areas such as collaboration, how people coordinate tasks, and how information is shared.

2.4 Research Methods

During the time spent on site at Airbus it was important to remain flexible with the research methods used. It was not always possible to predict when data collection could be undertaken, as opportunities often arose at the last minute. In addition to this, due to the need to respect the privacy and security concerns of the company, it was not always possible to capture audio or visual data.

Subsequently the methods used throughout this research were mixed, and choices were made based on the constraints and opportunities presented by the research context. These methods ranged from informal observations to semi-structured interviews and surveys.

The following section will provide a high-level overview of the data collection and analysis methods used in this thesis.

2.4.1 Ethnography

Ethnography is a methodology associated with the study, analysis and description of socially situated action. It derives from the field of anthropology and involves immersion in a setting in order to understand it. This methodology forms a vital part of this research and will be addressed in further detail within the literature review in Chapter 3 (along with the related methods of ethnomethodology and technomethodology).

Use: Ethnographic research forms the basis of Chapter 4 and Chapter 5. This thesis explores the use of ethnography in a design context.

2.4.2 Case Study

The Case Study is a common method across a number of fields, and its use generally stems from a desire to understand complex social phenomena as it allows researchers to "retain the holistic and meaningful characteristics of real life events" (Yin, 2009, p. 4). The method is of most use when asking 'how' and 'why' questions about a contemporary event with which a researcher has little or no control over. This method was appropriate for this research due to the ability to observe naturally occurring phenomena at Airbus.

A more formal definition of the Case Study method is as follows:

1. A case study is an empirical inquiry that:
    - investigates a contemporary phenomenon in depth and within its real life context, especially when the boundaries between phenomenon and context are not clearly evident.
2. The case study inquiry:
    - copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
    - relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
    - benefits from the prior development of theoretical propositions to guide data collection and analysis

(Yin, 2009, p. 18)

However use of the method raises a number of concerns such as a lack of systematic procedures being used, and the presentation of biased views. Therefore it is important for a researcher to try hard to report all evidence fairly. Some critics also suggest that there is little basis for scientific generalisation when looking at a single case (or small group of cases) in such detail. Yet the goal of a case study is not to achieve quantifiable generalisation, but instead to expand on or generalise theories (Yin, 2009).

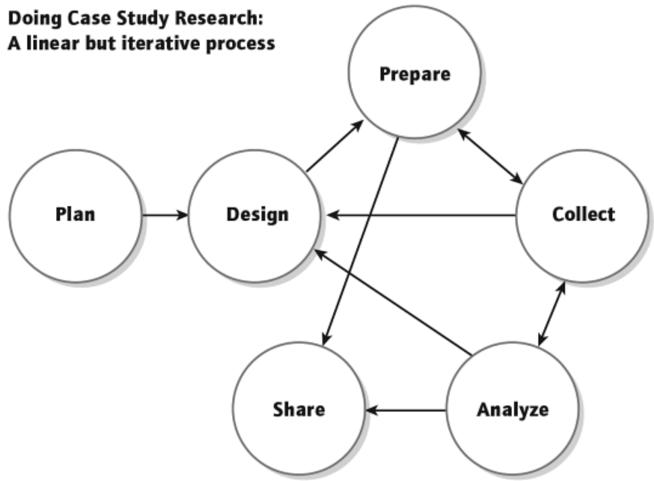

Figure 6 - Case Study Research Process (Yin, 2009)

Whilst ethnography or participant observation may be deployed within case studies, it does not depend solely on these as it could be done at a distance, through devices such as the telephone or internet (Yin, 2009).

Use: This thesis explores a case study of software development teams, and specifically Chapter 5 explores one particular project team as a distinct case study within this. However the method is accompanied by other approaches such as ethnography and surveys.

2.4.3 Activity Theory

Activity Theory is an analytic tool that can be used to frame data collection and analysis. It is a clarifying and descriptive theory (Nardi, 1996) that looks at 'Activities' as a minimal meaningful context for actions, and placing them within a social context (Kuutti, 1996). It looks at understanding and describing the 'context', 'situation', and 'practice' (Nardi, 1996) of activity. It can therefore be seen as a common vocabulary (Nardi, 1996) for descriptions.

Origins

Activity Theory (AT) has its roots in the Russian cultural-historical tradition that began in the 1920s and 30s. This is an approach that aims to understand individual human beings, as well as the social entities that they compose (Kaptelinin & Nardi, 2006). It was founded by Aleksey Leontiv, a disciple of Vygotsky, and who continued his work after his death.

The early ideas formed around the concept of a 'unity of consciousness and activity' and the 'social nature of the human mind' (Kaptelinin & Nardi, 2006). It studies individuals within a social and mediated context and looks at consciousness as embedded in a wider activity system where changes in consciousness are directly related to the materials and social conditions currently in an individual's situation. (Nardi, 1996). A number of key concepts exist, and some of these are summarised below.

Goals

"Human beings usually use computers not because they want to interact with them but because they want to reach their goals beyond the situation of the ``dialogue'' with the computer" (Kaptelinin, 1996, p. 25). When trying to establish the need for new or better systems, this needs to be kept in mind. What goals will the tool need to support and what is the non-computerized or existing equivalent of the activity?

Objects and Object Orientedness

Activity Theory has a strong concept of object-orientedness; that activity is directed towards something in the world. An object is a tangible or intangible thing that is transformed through collective activities. It can be shared for manipulation and transformation by participants in an activity (Kuutti, 1996).

Activities

Activities are a form of doing directed at objects (e.g. plans, ideas etc.) and transforming the object into an outcome motivates the existence of an activity (Kuutti, 1996). They are "the purposeful interaction of the subject with the world" (Kaptelinin & Nardi, 2006, p. 31). You can't understand subjects and objects separately. Interaction is initiated and carried out by a subject in order to fulfil its needs (the motivation) (Kaptelinin & Nardi, 2006). Activity Theory requires that the scope of analysis is extended from the study of tasks, towards a meaningful context of a subject's interaction with the world. This includes the social context (Kaptelinin & Nardi, 2006).

"Using a system does not normally have its own purpose; its meaning is determined by a larger context of human activity carried out to establish things that are important regardless of technology itself" (Kaptelinin & Nardi, 2006, p. 34). The most basic representation of an activity is the interaction between a subject and an object.

$$S \longleftrightarrow O$$

Mediation

Human beings (subjects) rarely interact with the world directly. Instead '*artefacts*' (or instruments) have been developed by humankind to mediate this relationship (Kaptelinin & Nardi, 2006).

A *community* consists of those people who share the same object, and the relationship between a subject and their community is mediated by *rules*. *Rules* cover both explicit and implicit norms, conventions and social relations within a community.

Division of labour mediates the relationship between objects and a community and this refers to the explicit and implicit organisation of a community as related to the transformation process of the *object* into the *outcome*. (Kuutti, 1996).

History/Development
Activities are constantly changing, and thus also have their own histories. These older phases of the activity often stay embedded in them as they develop. Thus a historical analysis of the development of the activity is often needed in order to understand the situation (Kuutti, 1996). Artefacts are created and transformed during the development of the activity and once again carry a historical residue (Kuutti, 1996).

Hierarchical structure of activity
In a given situation, there will be an intertwined and connected web of *activities*. *Activities* are realised through individual or cooperative *actions*. *Actions* within an activity are linked by the same *object* and *motive*. *Actions* are conscious processes and themselves consist of chains of *operations*, which are well-defined habitual routines. *Operations* begin as conscious *actions*, but once they become practiced enough they will be collapsed into a routine operation that is more fluid (Kuutti, 1996). A common way of explaining this is to think of driving a car. When you first start learning to drive, actions such as changing gear are formed of a series of very conscious actions such as putting the clutch down, and moving the gear lever. However, over time, these become routine and practiced, and eventually even the entire act of changing gear will become a subconscious operation.

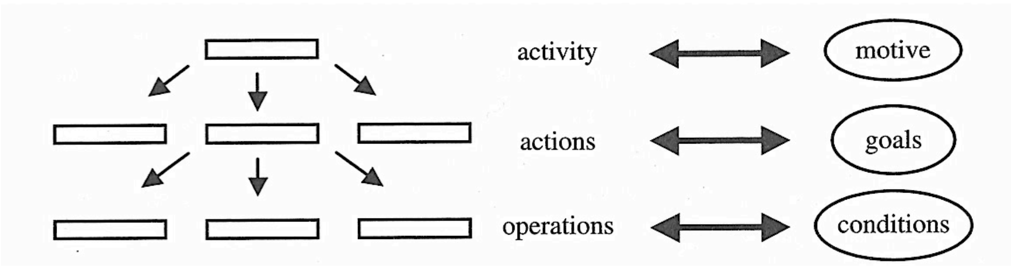

Figure 7 - The Hierarchical Structure of Activity (Kaptelinin & Nardi, 2006)

Contradictions
Activities are like nodes in crossing hierarchies and networks and they can be influenced by other activities and changes in the environment (Kuutti, 1996). Sometimes external influences change some elements in the activity system, leading to imbalances. This is when *contradictions* can occur. A *contradiction* is a misfit between elements, between different activities, and between different development stages of a single activity (Kuutti, 1996). They manifest themselves as problems, breakdowns, and clashes and they are key sources of development (Kuutti, 1996).

It is this ability to identify breakdowns that may make the application of a theoretical framework beneficial. Although whether these would be apparent without the use of AT is something that is not clear.

Example
The illustrative example seen in Figure 8 was used during this research to explain the entire *'Activity System'* (at a very basic level) to the team at Airbus.

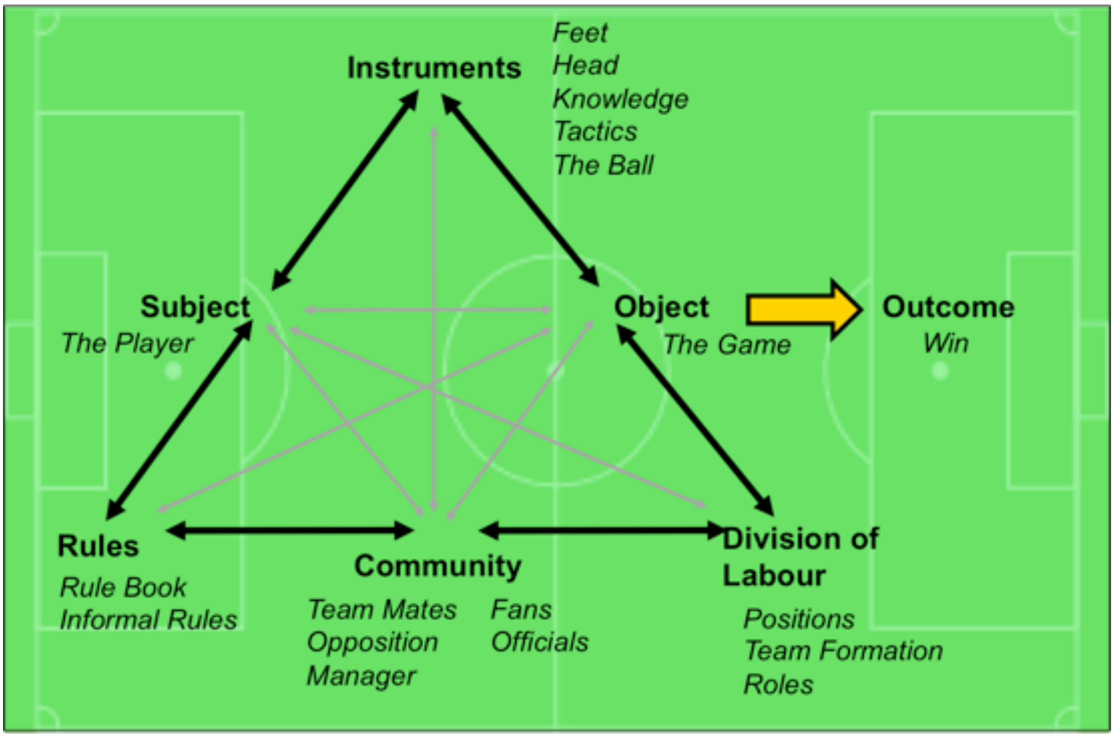

Figure 8 – Football as an Activity System

There have been concerns in the past of AT being hard to learn, and with the time spent learning being of dubious benefit (Nardi, 1996). In addition to this the benefits of using such an approach are not entirely clear, especially when looking at the field of systems design. However, the ability to look at Activity Systems and the mediated nature of work may help identify breakdowns and thus needs for support.

Use: Activity Theory is used in Chapter 5 to explore ways to guide and structure the studies of collaboration (specifically within aerodynamic design). However, its use was not as successful as anticipated and this will be reflected on in Section 5.2.7.

2.4.4 Triangulation & Mixed Methods

Triangulation within the domain of HCI research is the process of utilising other qualitative methods to evaluate research findings. It can be used to overcome the weaknesses or biases that may be present when qualitative data has been derived from a small number of observations. The rationale is that by using a number of methods researchers are able to avoid the limitations of any single method (Adams & Cox, 2008). The approach can involve collecting data from other sources (i.e. different locations or groups), using multiple observers (which was not possible in this research), looking at established literature (to find further support for findings), and using multiple methods to investigate the same phenomenon. This thesis uses both a mixture of sources and methods, as well as identifying similar issues in literature.

Use: In order to try and strengthen confidence in the ethnographic work described in Chapter 4 and Chapter 5 that predominantly focused on one or two projects. A mixed methods approach was used in Chapter 6, which introduced surveys and interview data across a broader sample of projects to try and triangulate the findings.

2.4.5 Surveys/Questionnaires

Questionnaires can be paper based or online and involve asking participants a series of either open or closed questions. Open questions allow participants to provide flexible free-form responses, whilst closed questions force participants to choose from a selection of set responses. The advantage to questionnaires is that they allow the same set of questions to be delivered to a wide range of participants with little effort.

When composing questions for a questionnaire it is important to consider the following points:

- Why you are asking the questions
- Who the results are for
- What you expect to find from the answers
- How you are going to analyse the data when you get them

(Adams & Cox, 2008)

A questionnaire is a useful method when you wish to identify information such as what people do in a particular situation, however if you wish to probe why they do this, another method (i.e. something that allows more freedom in responses) may be more appropriate (Adams & Cox, 2008).

Use: Questionnaires were used within the Focused Investigation stage of this research process (Chapter 6). They were used as a means of triangulating the ethnographic findings.

2.4.6 Interviews

Carrying out an interview is more than just reading out questionnaire questions to someone and writing down their answers (Adams & Cox, 2008). Instead they allow for questions to be probed in more detail. Interviewers may follow a schedule or pre-prepared questions (much like with a questionnaire) but they also have the flexibility to deviate from these where deemed necessary. When the questions deviate this is known as a semi-structured interview and it allows flexibility to probe previously unknown issues that arise during the interview (Adams & Cox, 2008).

Use: Interviews were used throughout this research in both a formal and informal context. Early ethnographic work included informal interviews, whilst the studies of collaboration discussed in Section 5.2 used surveys to provide context to later data collection. Interviews were a primary means of data collection in Chapter 6 where a number of interviews were carried out with software developers as an alternative to surveys. Finally interviews were used to evaluate the technology deployments in Chapter 8.

2.4.7 Diary Studies

Diary Studies are an experience sampling method that involves asking participants to record events themselves as they happen. This can be through answering predefined questions about events (known as feedback studies) or capturing media that are then used as prompts in interviews (elicitation studies) (Carter & Mankoff, 2005). Due to restrictions on photography and other privacy concerns within Airbus, this research used diary studies for the former of these two purposes.

Use: Diary studies were used within the research described in Chapter 5 to collect details of collaborative work within aerodynamic design teams.

2.4.8 Qualitative Data Analysis and Coding

Qualitative research is conducted through prolonged context with a field or real life situation. The researchers role is to gain a holistic overview of the context by capturing data from within it. Qualitative data can be extended text or images (including video) that are rich and holistic, but these often need to be processed for analysis (Miles & Huberman, 1994). Often the first part of this process is the coding of data. Miles and Huberman describe codes as 'tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study.' (1994, p. 56). The process allows researchers to condense a bulk of data into analysable units or categories that have common properties (Coffey & Atkinson, 1996). These codes can then allow researchers to retrieve and organise data.

The process of coding can use a set of existing codes (gathered from conceptual frameworks, hypothesis, literature, or previous studies) or it can be a 'bottom up' process that stems from the content of the data itself (Coffey & Atkinson, 1996).

Use: The majority of the ethnographic work was analysed at a high level, identifying themes through experience in the field. However meeting observations carried out in Chapter 5 were analysed using an existing set of codes. When examining the survey and interview data in Chapter 6, bottom up coding and categorisation were used to help examine and explore the data. Coding was also used to analyse the final participatory design workshop in Section 7.6.

2.4.9 Summary

This section has described the data capture and analysis methods that were used during this research. Some of these were more successful than others when applied in the domain at Airbus. For example AT was less effective at highlighting issues than anticipated, which was a disappointment considering the learning overhead involved. In general, the application and combination of these methods in a pragmatic and practical manner appeared to yield the most success. Throughout the remainder of this thesis the methods will be reflected on in further detail.

2.5 Literature Selection

The following chapter will provide an overview of literature that is related to both the process of identifying requirements and introducing software, as well as previous work within the domain of the case study (collaboration in software development).

Literature has been chosen to provide a background to the 'need' for new systems and the elicitation of requirements within the scope of software engineering. It also looks at the challenges that might be encountered when attempting this, particularly with a focus on collaborative software.

Ethnography played an important role in this work and a large section of the literature review is dedicated to providing a background to this method and the ways in which it can inform design. Participatory design is also a key focus of this work and a background to this design technique is provided.

Literature is included that looks at the process of introducing technology, ways to manage the inevitable change that will result from this, and some details of technology adoption and appropriation (i.e. technology in use).

Finally, a review is provided of literature related to the case study. Similar studies of collaboration in software development are outlined in order to provide the bigger picture of this work. In addition to this, the areas of rationale management, and meeting recording technologies are summarised as this links to the technologies that were eventually evaluated at Airbus.

Chapter 3

Literature Background

3.1 Introduction

As has been stated in Chapter 1, this thesis looks at a process for studying a context to identify needs (specifically within collaborative work), and involving stakeholders in a process for matching these to existing technology. This chapter will provide a background to current processes and methods for designing and introducing technology.

It will begin with a background to the use of tools and technology in industry to illustrate how central they have become and the relationship between technology and 'needs'. It will then discuss a brief evolution of system development processes and requirements engineering. During this, ethnography and its use in design will be discussed along with participatory design methods (which will become central to this thesis). Issues surrounding the introduction of technology and the management of the changes involved in this will also be discussed, with a particular focus on collaborative systems.

The final section of this chapter will look at literature relating to the case study of supporting collaboration in software development teams that became the main focus of this research. This will cover previous research in this field, as well as literature on the capture of design rationale as this became one of the major themes of the case study.

3.2 The Role of Technology

Technology and tools can bring a competitive edge to companies, as well as creating efficiencies. Historically they have been known to revolutionise industries, whilst also providing important efficiencies within work processes. In recent years, tools to support people collaborating remotely have had a great impact on the way in which teams conduct work.

3.2.1 The Role of Tools

"We live not merely in a technological world, but in a world that from our earliest years we imagine and construct through tools and machines" (Nye, 2006) *[preface].*

Humans have been using tools for at least 400,000 years. They have shaped us and are inseparable from our nature. However, the central purpose of these tools or technologies has not been to provide necessities such as food and shelter, as these goals were achieved early on in the existence of humans. Instead, technologies have been used for social evolution. In fact, technologies as necessities are constantly being redefined (Nye, 2006).

Today tools are still increasingly ubiquitous, and at times overwhelmingly so. If you look around at a typical work place, people will be using 'simple' tools such as pen and paper, more computational advanced tools, such as PCs, and collaborative tools like email to engage in their work.

3.2.2 Collaborative Tools

Historically humans have used tools to help support them when working or communicating with other people. Advances such as the telephone have allowed people to communicate when they are not face-to-face, something that is now often taken for granted.

Towards the 1980s the phrases groupware and Computer Supported Cooperative Work (CSCW) began to be used, along with labels such as collaborative computing, workgroup computing, multi-user applications and, CSCW applications (Grudin, 1994). These referred to the ways in which computing technology had evolved to support multiple users, performing tasks together.

Conditions had begun to emerge in workplaces that encouraged this type of system:

a) Computing technology had become inexpensive enough for it to be available to all members of an organisation.
b) The technological infrastructure supporting communication, and coordination, notably networks and associated software.
c) A wider familiarity with computers, leading to groups being willing to try new software.
d) Maturing single user application domains that pushed developers to seek new ways to enhance and differentiate products.

(Grudin, 1994)

These collaborative technologies have transformed the way that individuals and organisations operate, but are particularly difficult to introduce. This will be discussed in more detail later.

3.2.3 Needs & Technology

Having discussed that this thesis will look at 'needs', it is important to discuss what this means.

Within social theories such as AT (previously discussed in the Methodology chapter) a need is seen as the ultimate cause behind human activity. "Having a need means that something should be present in the environment" (Kaptelinin & Nardi, 2006, p. 60). Within the field of computing, a need can be seen as something that precedes and drives 'requirements' (what the system must do). It may not be a fundamental human 'need' such as consuming food and water, but it is something that may help people "achieve their goals more effectively if they were supported differently" (Preece, Rogers, & Sharp, 2002, p. 172). It may not be something that someone could immediately articulate but could be discovered through studies of users and contexts (to be discussed later).

A traditional interaction design process as illustrated in Figure 9 shows the identification of needs as driving the design of new technology.

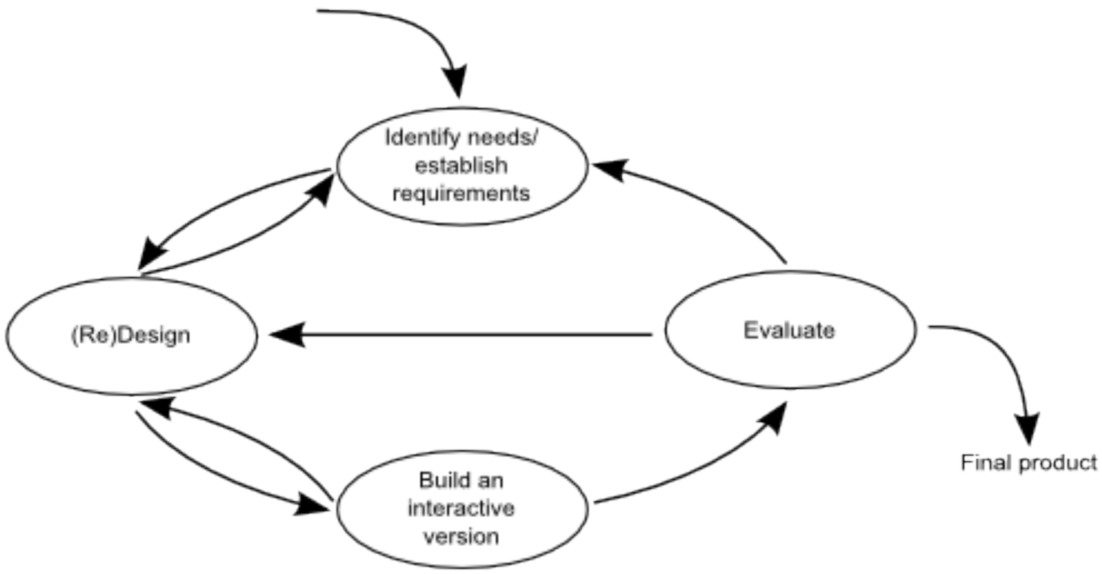

Figure 9 - A Simple Interaction Design Model (Preece, Rogers, & Sharp, 2002)

In her discussion of design of interaction 'in the wild', Rogers (2011) suggests that the concept of needs is now less important. Instead the focus should be on creating and evaluating new technologies in situ, rather than looking at existing practices and suggesting design implications and system requirements. New technologies, she states, are not necessarily designed for specific user needs. However, Crabtree et al. (2013) suggest that, whilst these technologies may not be designed with a clear set of needs in mind, these begin to emerge as design takes place.

These differing views show that the relationship between needs and technology is quite complex. Often technology is created in response to a need (as indicated above), yet technological advances can also change and alter these needs. For example Norman (2010) states that in reality often technology comes first, and needs last.

"The technology will come first, the products second, and then the needs will slowly appear, as new applications become luxuries, then 'needs', and finally essentials….What is a 'need' once we have gone beyond things biologically essential in life?...Are technological means of communication essential needs? Today yes, they are. Reading and writing are fundamental needs" (Norman, 2010, p. 42).

1000 years ago people didn't 'need' email. It took the existence of technologies to make these activities possible, the need then slowly formed. Thus 'needs' are not static, and are relative to the technological advances.

As a result of this Norman (2010) debates the use of studies of people and their lives to discover hidden, unmet needs. Whilst it is a logical step, and can lead to incremental innovation, he suggests that history shows that this is not how brilliant, earth-shattering innovations come about. This, he claims, is more due to inventors doing what 'inventors do', and these 'technologists' have little understanding of this 'research stuff'. Evidence for this is provided in the form of the development of the Internet, Aeroplanes, and SMS messaging. These were driven by technology, and often not even used in the way they were intended, SMS messaging being a key example of this. Even multi-touch technology, which is so common today, took two decades to move from the research lab, to appearances in everyday products. The Graphical User Interface (GUI) wasn't uncovered through user studies, instead the developers at Xerox used their intuition and personal observations as guidance (Norman, 2010).

Norman claims that innovations are usually excellent concepts that are ahead of their time and ethnographic observations are instead useful for uncovering difficulties people have, and their everyday workarounds. Thus there appears to be the need for a bridge between establishing these unmet 'needs', and matching them to the technology that has already been developed ahead of time by these 'inventors'.

It is also worth noting Norman's mention of 'workarounds'. These are the ways in which people adapt the tools they have to achieve what they are doing. They may not always need a tool that can do 'everything' because they can adapt it.

3.2.4 Technology and Needs Summary

Technology and tools are ubiquitous in the workplace, and using them is a natural human trait. When looking at introducing technology it is important to consider the 'needs' of the people and the organisation, and this is especially key when looking at tools to support the more social and collaborative aspects of work. This may not necessarily have to prompt the development of new tools, as innovators may have already developed appropriate technology. However needs will help define which technology should be introduced.

This section has looked at the use of tools as well as the 'needs' that drive their introduction. It has also highlighted that innovations often come before these needs, rather than technology being driven by these. Needs are not static, and it could be suggested that they are in fact relative to technological advances.

The next sections will look at the way in which needs are formalised into requirements within the broader domains of systems and software engineering.

3.3 Software & Requirements Engineering

New computer-based tools are often created through a process known as software engineering. The goal of this process is the cost-effective development of software systems. It emerged as a field as a result of the increasingly complex software systems being produced and the failure of informal approaches when engineering these (Sommerville, 2001).

Systems engineering began as a discipline for determining the best way to configure hardware components into physical systems such as ships, railroads, or defence systems (Boehm, 2006). Software engineering is a sub-section of this that looks at the development of software components. Software engineering began as a formal and mathematical approach to specifying software and often the process of producing requirements was left to others, including hardware-oriented systems engineers. This led to problems with defining non-precise notions such as 'users'. It also originated as a sequential approach to defining requirements, formulating, implementing, and testing solutions. However this changed as systems became more user-intensive and it was realised that requirements could not always be specified in advance. This led to the development of alternative software engineering processes (such as evolutionary, spiral (see Figure 10) and agile) (Boehm, 2006). These processes are more iterative and flexible to unexpected changes.

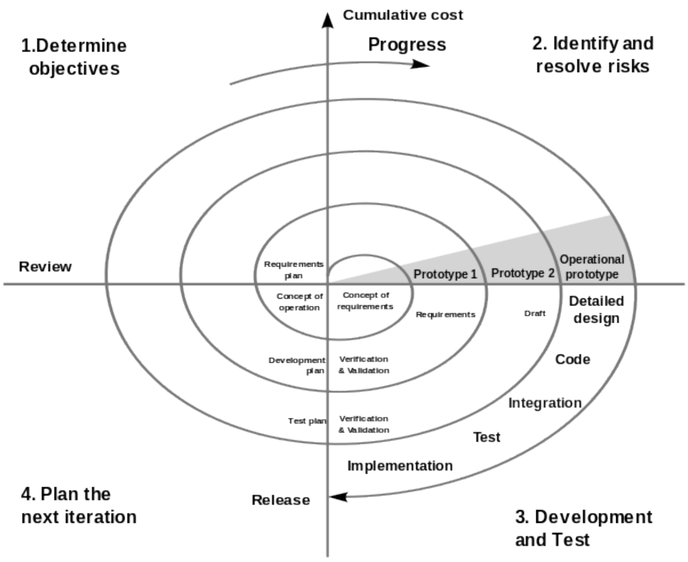

Figure 10 - Spiral Model of Software Development (Boehm, 1988)

3.3.1 Soft-Systems Engineering

Within the traditionally formal approach of Systems Engineering, some researchers have looked at ways to study and represent everyday problem situations. Checkland (2000) has attempted this through the introduction of 'Soft-Systems Engineering'. This approach tries to model 'purposeful human activity systems'. However, this is not always possible in one single model, and so a number of models are used. These models aim to embody the pure ideas of purposeful human activity and they are then used as a source to question the real world (see Figure 11).

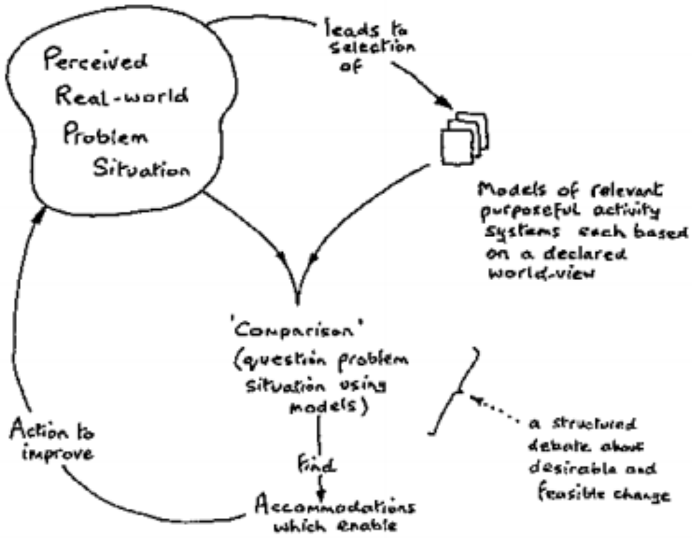

Figure 11 - Soft Systems Approach

The process has seven stages. The first two stages involve entering the problem situation to find out about it in order to express its nature. The third stage involves creating 'root definitions' from these findings, and the fourth involves modelling these. The next two stages use the models to structure further questioning of the situation and attempt to define the changes that could improve it. Stage seven then takes the action to improve the problem situation. However it is important to note that these stages will probably evolve in a more organic manner than stated.

To reflect this, a four-stage model has also been described:

1. Finding out about a problem situation, including culturally/politically.
2. Formulating some relevant purposeful activity models.
3. Debating the situation, using the models, seeking from that debate both
    a. Changes which would improve the situation and are regarded as both desirable and (culturally) feasible, and
    b. The accommodations between conflicting interests that will enable action-to-improve to be taken.
4. Taking action in the situation to bring about improvement.

(Checkland, 2000, p. 21)

A fundamental process within soft-systems engineering is that of building 'rich pictures'. These are drawings that indicate the elements in a situation. Checkland felt that pictures were a better medium than linear prose for expressing relationships whilst also being useful for generating discussions (Checkland, 2000).

Whilst this method sits within the domain of systems engineering, it is still applicable when devising actions related to changes in software and other technology. This more flexible approach allows for descriptive models of complex situations to be developed, and helps define changes that may be needed. However, it is often still important to be able to formalise these proposed changes in a language that developers will understand.

The next section will look at a fundamental part of both systems and software engineering. This is the elicitation and representation of requirements.

3.3.2 Requirements Engineering

Requirements can be seen as "a high-level, abstract statement of a service that the system should provide or a constraint on the system" (Sommerville, 2001, p. 98). Requirements engineering forms a pivotal role in systems and software engineering. It is the process of identifying needs and formalising these into a list of features and constraints. Sommerville (2001) describes this process as having four high-level processes as follows:

- ***Feasibility study:*** taking an outline description of the system and how it should be used, and carrying out a short study of whether the system contributes to organisational objectives, the technological and cost constraints, and whether the system can be integrated with existing infrastructure. This results in a report recommending whether or not system development should continue.
- ***Requirements elicitation and analysis:*** working with customers and end-users to find out about the application domain, the services the system should provide, the required performance of the system, and any constraints.
- ***Requirements specification:*** creating a detailed description of what the system should do (and any constraints)
- ***Requirements validation:*** ensuring that the requirements actually define the system that the customer wants.

By establishing needs for system support within this thesis, it is important to consider the role of requirements engineering. Requirements provide a way of formalising the needs and constraints within the application domain in order to understand how existing technology can satisfy these.

Requirements can be specified in a number of ways but they are usually split into functional, non-functional, and domain requirements. These can be summarised as follows:

- *Functional requirements:* These state the functions that the system should provide, how it should react to inputs, and how it should behave in particular situations.
- *Non-functional requirements:* These are constraints on the system such as time constraints, or constraints on the development process.
- *Domain requirements:* These reflect the characteristics of the application domain and may be functional or non-functional.

(Sommerville, 2001)

These requirements are written up to create a software requirement specification that will then be distributed to stakeholders such as senior management and software developers. This document will form the basis of the development process, although intermediate forms of representation are often used to bridge the gap between requirements and design. This can include a software design specification that adds further details to the system requirements and provides an abstract description of the software design (Sommerville, 2001).

The next section will look at techniques for identifying needs and eliciting requirements, especially in relation to studying the context of use.

3.4 Studying Context

"Design methods define a coherent series of actions that lead a team, we hope, to a well-designed system." (Beyer & Holtzblatt, 1999, p. 32). This system is not just the new technology, but the entire system of work where this technology is being used. This is because, when introducing new technology, it is not just the technology that changes, but also the work practices surrounding its use.

Many system design processes accept that work practices will need to be changed. However, *"successful systems offer a way of working that customers want to adopt"* (Beyer & Holtzblatt, 1999, p. 22). For this to happen effectively, the current work practices need to be thoroughly understood.

"Great product ideas come from the marriage of a designer's detailed understanding of a customer's need and his or her in-depth understanding of the possibilities introduced by technology. The best product designs result when the product's designers are involved in collecting and interpreting customer data and appreciate what real people need" (Beyer & Holtzblatt, 1999, p. 32).

Typically most product development design lifecycles involve an initial form of contextual analysis that will later inform design. This may contribute to a set of requirements, which then must be turned into an actual design based on the contextual understanding that has been gained (Judge, Neustaedter, Tang, & Harrison, 2010).

However, within the field of computing, it has taken time for this realisation to come about. The following sections will provide a historical perspective on the way in which people have gone about designing technology through understanding the context of work.

3.4.1 The History of Understanding Context

By understanding the psychology of humans, and the cognitive processes involved in tasks, systems can be designed to better support the interface between the computer and a user (e.g. (Grudin & Grinter, 1995)). Over time, the location of the user interface has been pushed farther and farther out from the computer, initially towards the user, and then into the work environment (Grudin, 1990). "We are beginning to see the focus of user interface design extend out into the social and work environment, reaching even further from its origin at the heart of the computer" (Grudin, 1990, p. 262).

As it moves into the social environment and context of work, the community has realised the need for understanding the sociological processes involved in this. As Grudin & Grinter (1995) state, "the process of incorporating social knowledge has begun" (pp.58). In the 1980s sociologists and anthropologists began to look into how people worked, in order to inform systems design. Applications to support this more social side, have all the usual interface design issues, and more, and this requires a deep understanding of the social aspects of the work environment. This understanding is particularly vital in the area of CSCW where the systems "by their very nature, are more complex than single-user systems" (Rogers, 1994, p. 67). Social, motivational, economic and political factors may need to be taken into account (Grudin, 1990).

Subsequently, the systems development community began to look at methods for studying this social and contextual side of work. Methods for understanding 'the social' can be perceived as less precise and with a weaker science base (Grudin, 1990). Yet whilst being perceived as less precise, it is also more difficult. Group processes often vary across people and contexts, and can unfold over time, and in different locations. This also needs to be taken into account when developing systems to support social aspects, yet generalising from observations can be difficult (Grudin, 1990).

Figure 12 shows the stages of the user interface and the methods and costs of evaluating these as perceived by Grudin (1990).

	Level 1. Interface as hardware	Level 2. Interface as software	Level 3. Interface as terminal	Level 4. Interface as dialogue	Level 5. Interface as work setting
Principal users	Engineers/ programmers	Programmers	"End users"	"End users"	Groups of end users
Interface specialist disciplines	Electrical engineering	Computer science	Human factors, cognitive psych., graphic design	Cognitive psych., cognitive science, (dramatic arts?)	Social psych., anthropology, organizational...
Research methods	Largely informal	Largely informal	Laboratory experiment	Wizard of Oz, thinking aloud, data capture	Ethnographic, contextual, participant observer
Duration of basic events studied	Microseconds/ hours	Milliseconds/ hours	Seconds	Minutes	Days
Cost of evaluation	Lowest	Low	Moderate	High	Highest
Precision, generality	Highest	High	Moderate	Low	Lowest
Major focus	1950s	1960s-1970s	1970s-1990s	1980s-	1990s-

Figure 12 - Summary of the distinctions across levels of interface focus. (Grudin, 1990)

Grudin lists a number of methods for understanding the work setting, including 'ethnographic, contextual, and participant observer'. As time has gone on, the number of approaches for understanding work situations has increased. A key protagonist in this area was Lucy Suchman who believed in the situated nature of work within a social context, which she describes as 'situated action'. These actions are impossible to understand without this context (Suchman, 1987). Suchman's work led the community to look for further ways of understanding context and there are now a number of approaches towards this.

Previous ways of involving users in design and understanding their work practices and behaviours have often involved techniques such as surveys and interviews. However there are problems with these approaches as behaviour is likely to be different in reality to how it is described by those who do it (Simonsen & Kensing, 1997). Consequently, it is important to study and directly observe processes and behaviour in order to gain a more realistic understanding of the situation. The following section will discuss some of the options for studying context and provides examples of their use.

3.4.2 Fieldwork in Design

'Fieldwork' is often used as an umbrella term for spending time in the field and its interpretation is quite flexible.

Bellotti & Smith (2000) reflect on their use of this approach during the design of a paper based Personal Information Management (PIM) system. Their design approach involved an iterative process combining fieldwork and design. A key feature of this process was that both the designer and engineer carried out the fieldwork. The authors (the design team) claim that this combination of fieldwork and design enabled them "to see beyond what [they] wanted to build, to what would be beneficial as a solution to some of the problems with the current PIM technology" (pg. 227).

The Process

The design process involved three phases in order to develop an understanding of PIM and to obtain feedback on design ideas (by explaining and demonstrating the envisaged system and asking specific questions related to it). The first phase involved four in-house pilot show-and-tell interviews to develop field questions and gain preliminary feedback about initial design ideas. The second phase involved eight in depth, in-situ, show-and-tell interviews in order to explore developing areas of interest and to get feedback on a more clearly defined system description. The third phase involved 24 in-depth interviews to improve confidence and verify specific observations.

The rationale behind the three phases of fieldwork was as follows:

- To iteratively develop a pertinent and comprehensive set of questions around the area of interest.
- To evolve the focus away from any pre-existing assumptions towards a more evidence based understanding (especially focusing on unforeseen problem areas).
- To develop hypotheses about the 'problem area' based on a qualitative analysis of the interviews, then testing these by asking more specific questions to a wider range of interviewees in phase 3 (to gain more quantitative data).
- Carrying out the first phase in-house with employees of the researchers' organisation meant that any technical issues could be ironed out first. Adjustments such as bringing paper based prototypes to interviews for evaluation could be made for phase 2.

Reflections on the Process

Bellotti & Smith (2000) report that the initial feedback on the paper-based GUI prototypes was fairly luke-warm. There were a number of problems with them, such as people having different preferences for paper size and people wanting different layouts. The users were also not enthralled by the idea of a paper-based system in general.

For a while, the team stuck to a paper-based meeting-notes management system but as the in-depth interview stage progressed they realised that outside of their Xerox offices, high speed sophisticated scanners were scarce (and these were vital for scanning in the paper documents in order for them to be processed). Also they realised that if people were unwilling to file paper notes due to it being problematic and time consuming, they were unlikely to take kindly to an extra scanning step in the process.

The results from the in-depth interviews were very disappointing to the team as they had to return to the drawing board. This included re-examining the data to look for new ideas for "an interesting application". From this analysis, three key findings stood out:

- Email was the main document transfer vehicle
- Email was the main online tool for coordination and collaboration and thus contained a lot of information about the documents that it was used to convey.
- Paper was used a lot to support PIM but examples of activity existed that highlighted the need for embedded information capabilities online in productivity tools, in particular email. Some interviewees had left email in their inboxes as to-do items. The team felt it was clear that people wanted to use applications that were already open to support PIM and in this case email seemed to be the application open most of the time.

Whilst paper is lightweight, cheap, flexible, and intuitive to use, it is also 'ever-present'. This may explain why it formed such a key support tool in PIM practices. Yet users did not want to have to scan this in and the interface was not flexible enough. The authors began to realise that email also has the property of being 'ever-present' and thus is easy to get hold of when needed, and is regularly checked. Thus there may be potential to utilise this instead.

Due to change in focus of the study, the team felt it was necessary to conduct another round of in depth interviews, with a stronger focus on the new phenomena. These set out to confirm or dispel their new hypotheses that email could be a locus for support. These interviews were shorter and questions focused on meetings, email, phone calls, note taking and use, and use of technology such as PCs, PDAs, printers, and scanners. Amongst the findings from these interviews was evidence to suggest that email may be the most important and frequently used application and is usually running all day whilst being monitored constantly.

The design team took the qualitative and quantitative findings from the 3 sets of interviews and developed four *design principles* based on this evidence. These were:

- Embedding PIM in an application that supports on-going work
- Flexibility
- Lightweight
- Simplicity

They then began to prototype an embedded PIM system that looked much the same as an email application. It stimulated the behaviour of an email inbox but with documents in it as well as the ability to carry out filtered views and searches. Following the principle of 'embedding PIM in an application that supports on-going work' the team implemented a 'sticky notes' system to mimic the ubiquitous real life use of them in the office (as noted during the fieldwork). They also added easy features for creating 'to-do' lists within the application. During the design and evaluation process the tool was used for over 6 months by the engineer in the design team who found that the implementation of the principles of 'flexibility', 'lightweight', and 'simplicity' when creating collections of information, made content very easy to retrieve. However the system at this time of their paper being written (2000) had not been evaluated beyond the engineer using it.

Summary

Despite this lack of evaluation, some useful insights can be gained from the process followed in this case study. Firstly, it shows that by going into the field, talking to people, and showing prototypes, useful feedback can be gained, which can fundamentally change the beliefs held by the design team. However it also highlights some of the dangers of going into the field with pre-conceptions and technology focused design ideas. The authors here wanted to introduce PIM technology, and they went into the field with prototypes to discuss this. The concept of first establishing *'needs'* is not discussed. They set out to introduce technology, based on their own pre-conceptions and assumption and this can lead to problems, such as the assumption that users would have scanners handy to them, and want to use them.

However, the study also highlighted how the team used their findings to emphasise 'design principles' such as the need for embedded and flexible tools. These could then drive their development work. By establishing the design principles from their work in the field, they were able to better ground their future design. Yet, perhaps they should have set out to do this initially. These design principles are also worth noting, as they may be applicable on a more general level, beyond PIM.

The authors in this paper took a fairly structured approach to their fieldwork, which consisted of interviews and prototype 'show and tells'. However, fieldwork can also include less structured observations.

3.4.3 Contextual Design

Contextual Design is a more specific and formalised method for capturing context that helps cross functional design teams to come to agreement on what the needs of the customer are, and how to design a system that best meets these. Contextual Design is a process that deals with the *front end* of design and involves the collection of data to establish which 'needs' should be addressed. It is a flexible process that can be carried out in a detailed manner, or in a more quick and dirty way, omitting steps if they aren't applicable. It focuses very much on developing and maintaining a shared vision, purpose and direction across a whole design team. The six main stages of Contextual Design are as follows (from (Beyer & Holtzblatt, 1999)).

Contextual Inquiry

This stage uses one-on-one field interviews with customers to understand their *needs*, their *desires*, and their *approach to work*. Once this is complete, team interpretation sessions take place where the cross-functional team share their interview insights and perspectives. The team can then capture key issues, draw models of the work and develop a shared view of the customer and their needs.

Work Modelling

The stage sets out to ground the design team's understanding through showing the work of the individuals and organisations in diagrams. The models include: 1) the flow model - showing communication and coordination, 2) the cultural model - showing culture and policy, 3) the sequence model - showing the steps performed to accomplish a task, 4) the physical model - showing the physical environment as it supports work, and 5) the artefact model - showing how artefacts are used and structured when doing the work.

Consolidation

The consolidation stage sets out to make visible the common patterns and structure from the individual interviews and observations. An *affinity diagram* can help achieve this by creating a wall-sized hierarchical diagram of all the issues, grouped into categories. Together the affinity diagram and consolidated models (from previous models) produce a single picture of the customer population.

Work Redesign

The aim of this design phase is to create a vision of a redesigned work practice in the form of storyboards that include the system, its delivery, and support structures to ensure its success. The process involves bringing the team together to discuss the consolidated data and develop a conversation about "how technology helps people get their jobs done, rather than on what could be done with technology without considering the impact on people's lives." (Beyer & Holtzblatt, 1999, p. 39).

User Environment Design

The *User Environment Design* (UED) shows the 'floor plan' of the new system, detailing each part of the system, how it will support the users' work, the functions available, and how the user navigates the system (though not focusing on GUI elements).

Mock-up and Test with Customers

This phase uses techniques such as paper prototyping to evaluate the system as early as possible with real users in the workplace. Through this process users may discover problems that they can then work with the designer to address through iterative redesign.

Once these phases of the preliminary Contextual Design process are complete, the team can begin to implement the system.

Criticisms

Judge, Neustaedter, Tang, & Harrison (2010) discuss issues with moving from a phase of contextual analysis to design. The challenge is in moving from these findings about the users, their activities, and needs into design requirements, constraints and implications that are applicable to design. Thus, whilst the process of Contextual Design considers the capture and representation of contextual information, and makes attempts at involving users, it does not explicitly address the process of making use of this in the design itself.

Judge, Neustaedter, Tang, and Harrison (2010) list a number of potential problems with this transition, (specifically focusing on Contextual Analysis):

- Designers are often required to draw their ideas from huge amounts of data gathered from the users' work domain (including affinity diagrams etc.). With such large amounts of data to draw from, how can designers establish the most important and relevant information for the design?
- There may be some degree of disconnect between the types of data collected during the contextual analysis and the information needed to guide the design. The contextual analysis artefacts may not map well to the artefacts or information needed during design.
- Designers are often required to be in two modes of thinking; analysis-thinking and design-thinking. They must be separated based on where the designer is in the design lifecycle. "Contextual Analysis often requires deductive reasoning and design typically requires inductive reasoning." (Judge, Neustaedter, Tang, & Harrison, 2010, p. 4489). There may be problems faced when designers have to switch between these two forms of reasoning.
- There may be problems with transferring knowledge if it is not the same individuals carrying out the contextual analysis and design.

The issue of transitioning from an analysis of a context, to design is still one that raises much debate. In fact this will be discussed further in relation to the use of ethnography in design.

Contextual Design Summary

Contextual Design emphasises the need to understand the users and their work environment in-depth, as well as spending time in the workplace to achieve this. It also highlights customer involvement in design work, beyond just studying them. The process makes use of a number of descriptive models, which create a shared understanding across the design team. Mock-ups are an increasingly common means of getting user feedback on designs and are a key way of sharing visions for re-designs in an accessible manner.

In this research project, it is important to take into account the working environment, as well as work closely with users to gain their input and feedback on ideas for change. However, as this work will be predominantly carried out individually, there is less need for the more team-focused stages of the process. Although creating representations of work can be key for communicating to other parties too.

Additionally, the need for mock-ups may be reduced if existing systems are introduced, but the concept of trying them out in the field before carrying out a full deployment is something that should be considered.

3.4.4 Summary

Contextual Design and Fieldwork are just two examples of means for understanding context during design but this chapter has attempted to highlight their benefits. Another method that is often considered under the umbrella term of 'fieldwork' is Ethnography. This is a technique that involves immersion within a cultural context in order to understand the nature of work (or other activities).

In fact Ethnography can be considered to be an entire methodology, and its use spans beyond and originates outside the field of design. The next section will discuss Ethnography in detail, especially the debates that exist around its use in design, along with the more practical details of its use.

3.5 Ethnography

3.5.1 Introduction

Ethnography originates from the field of anthropology and has been used to study work as far back as the 1930s, subjecting these occupations to social scrutiny (Button, 2000). Over the years it has become an increasingly popular method for capturing contextual data during systems development. It is a very useful technique for understanding settings in depth and is powerful when successfully incorporated into the systems design process.

"Ethnography is not a specialised way of looking at the world, in fact it could be seen as a ubiquitous but unnoticed feature of everyday life" (Crabtree, Benford, Greenhalgh, Tennet, Chalmers, & Brown, 2006, p. 61). People analyse their everyday ethnographies of what is going on around them, drawing their own conclusions. The key difference is that social science researchers will do this in a more formal and structured manner.

The following sections will examine ethnography in depth as this became a key technique used within this research.

3.5.2 Background

Ethnography was originally developed by anthropologists to understand social mechanisms in 'primitive' societies (Sommerville, Rodden, Sawyer, Bentley, & Twidale, 1992). Bronisław Malinowski is known as the founder of ethnography. When carrying out fieldwork studies of Trobiand islanders he took the step of immersing himself in their lives and living with them for a period of time. Through this he learned their language, participated in their customs, and collected first hand recollections of their way of life. This immersion became a key feature and pre-requisite of future ethnographic studies (Button, 2000).

Previously anthropology had been more concerned with documenting what members of other cultures 'did', but ethnography focused more on understanding the experiences of these cultures through participation in everyday life. Ethnography advocated long term, immersive fieldwork, combining fieldwork and participation (Dourish, 2006).

Button (2000) feels that when referring to ethnography in the study of engineering and design work, it is often being used as a proxy for fieldwork. "…the ethnographic tradition and what is has involved in an overarching presence, vaguely felt but never directly confronted in many of these examinations" (Button, 2000, p. 321). Anderson also feels that there is a misconception. "To go into the field does not necessarily mean doing ethnography, nor should it" (Anderson, 1994, p. 156).

Ethnography is often used to describe any in situ, qualitative studies (Dourish, 2006) and it is often mistaken for an information gathering approach (more like fieldwork) but it also involves an 'analytic mentality' (Button, 2000).

3.5.3 Analysis

Many of the complexities of ethnography arrive in the analysis of the data collected, and the way in which this is represented and put to use in processes such as systems design.

Traditional ethnography as used in anthropology concerns firstly the collection of data through first hand participation, and then the organisation of the data in terms of social theory to account for what has been observed. When it came to creating an account of the culture of the islanders, Malinowski constructed his own interpreted description of the life that he was immersed in from a 'functionalist' standpoint, which provided an explanatory framework for it. In fact, the analytic framework is not applied after the observations, but it conditions the observation in the first place; meaning that any description produced in this way is from the point of view of the theory (Button, 2000).

However, Button (2000) questions the application of theories to observations about society, as the resulting accounts are essentially a 'secondary account'. For example, when asking a person in society what they are doing, they are unlikely to express it in such theoretical terms, instead they may provide a more 'lay' discussion of what they are doing. Members of society have their own organised descriptions of what they do and the of ethnographic work is to "present a portrayal of life as seen and understood by those who live and work within the domain concerned." (Hughes, Randall, & Shapiro, 1993, pp. 125-126). Thus this raises the question of the appropriateness of applying theoretical analysis, especially when using the 'data' for systems development.

Ethnography as used by sociologists was intended to inform other sociologists and to some extent inform those developing social policies. 'Ethnographies' of design often have more 'practical' goals, such as informing system designers developing technology for that domain.

In addition to this, the background of those doing the studies is changing. Initially they would have a background in sociology or anthropology but psychologists or even computer scientists have carried out more recent studies. In fact, as Button (2000) suggests, much of the work is not actually informed by the traditions of ethnography, instead it is closer to that of a distinct domain known as ethnomethodology.

3.5.4 Ethnomethodology

There are two fundamental but different ways in which ethnographic materials are reported:
1) Through formal analysis, which describes the ethnographic materials in terms of coding schemes, taxonomies, grand theories or narratives, models and other situationally absent descriptions.
2) Ethnomethodologically, through thick description of the practical reasoning exhibited by members in the unfolding course of their activities together.
(Crabtree, Benford, Greenhalgh, Tennet, Chalmers, & Brown, 2006, p. 61)

Ethnomethodology shifts the emphasis away from the production of theoretical accounts of social activities towards an emphasis on descriptions of 'accountable practices' (Button, 2000, p. 325). It may utilise the same fieldwork techniques for data collection, but is not focused on the application of theories to this.

Ethnomethodology is not involved with taking an external or secondary view of work, instead "it seeks to describe social institutions and structures from within the midst of their daily operation….[this] means identifying and elaborating the methods by which ordinary members of society construct and reproduce the stable structures we all recognise as characteristic of social life" (Anderson, 1994, p. 157).

Ethnomethodology is concerned with unpacking the 'naturally accountable' work of a setting. "The object of our studies is whatever is ordinary and mundane about the people we study" (Crabtree, Rouncefield, & Tolmie, 2012, p. 25). It is the ethnographer's (or ethnomethodologist's) role to be the 'professional stranger'. It is about seeing or hearing people *doing* their work and to reflexively organise what they are doing. This is with the aim of unpacking it, describing it carefully, and making it available to analytic account and design reasoning. The true art of this is being able to make this visible in a way that "anyone else looking…might also be able to see that it does indeed work in just the ways you say it does" (Crabtree, Rouncefield, & Tolmie, 2012, p. 37).

Summary

The use of ethnography or ethnomethodology continues to cause debate. Whilst applying a theoretical framework may have initially been for communication and generalisation within anthropology and sociology, it may also provide a structure to the analysis in a design context. However, it is also important to consider the true accountable nature of the work when designing for a context as this is where the real details of the work lie.

This research initially took a more traditional perspective of ethnography, but later work moved towards an approach similar to ethnomethodology. Reflections on these methods will be provided in later chapters.

Whilst this debate continues as to what ethnography comprises, so does the issue of the use of ethnography in informing design. The next section will discuss this from the perspectives of both 'ethnographers' and 'ethnomethodologists'.

3.5.5 'Ethnography' in Systems Design

Ethnography is a descriptive rather than prescriptive technique and the role of the ethnographer is to act as a bridge between the domain system and the designer (Hughes, Randall, & Shapiro, 1993). However Anderson (1994) suggests that there may be conflicts when carrying out ethnography for design purposes as the designer's demand for prescriptive requirements specification may not fit with the ethnographers 'staunch refusal' to be prescriptive in their descriptions.

To put it simply, "in a design context the aim of ethnography is to develop a thorough understanding of current work practices as a basis for the design of computer support" (Simonsen & Kensing, 1997, p. 82). Today ethnographies are an accepted feature of IT research and systems design. They elaborate the accountable character of interaction and collaborative work or organisations and technology in use (Crabtree, Benford, Greenhalgh, Tennet, Chalmers, & Brown, 2006).

The role ethnography can play is often at an early stage of design when exploring the problem space. Ethnography is often used for requirements capture when in fact fieldwork is what is required. Whilst ethnography can be considered to be a form of fieldwork, the analytic perspective that it brings is often seen to set it apart. For example, Atkinson and Hammersley (1994) suggest that ethnography is a form of social research that has a strong emphasis on exploring the nature of social phenomena, rather than setting out to test a hypothesis, often within a small number of cases (or even just one case). These open and analytic ethnographies can make a contribution to design in the form of exploring the perceived problem space, bringing more novel and deep design possibilities to light.

Things that are originally perceived as problems may not be what they seem and may in fact be behaviours that are "exquisitely designed" for the practicalities that individuals have to deal with. What may seem to be an inefficiency or redundancy may actually be precision engineering and if designers are not aware of these details, their solutions may actually make things worse (Anderson, 1994). Ethnography can help designers understand the problem in enough detail to realise the 'real' problems. It is important to understand the intricacies of a situation before you write behaviour off as irrational and inefficient. Therefore perceived problems should be thoroughly considered before interventions are made. "Brokenness is in the eye of the beholder. If you cannot be sure it is broken, think twice before setting out to mend it" (Anderson, 1994, p. 178).

Ethnography is not a ready-made solution to design. However its methods can help to influence and inform systems design in a variety of different ways. Based on their own experiences with ethnography in systems design, (Hughes, King, Rodden, & Anderson, 1994) identify a number of different uses for it.

- ***Concurrent ethnography*** -> where design is influenced by an on-going ethnographic study taking place at the same time as systems development.
- ***Quick and dirty ethnography*** -> where brief ethnographic studies are undertaken to provide a general but informed sense of the setting for designers.
- ***Evaluative ethnography*** -> where an ethnographic study is undertaken to verify or validate a set of already formulated design decisions.
- ***Re-examination of previous studies*** -> where previous studies are re-examined to inform initial design thinking.

(Hughes, King, Rodden, & Anderson, 1994, p. 432)

More recently ethnography has been used to help scope out design spaces. Crabtree, Chamberlain, Davies, Glover, Reeves, Rodden, Tolmie, and Jones (2013) discuss using 'sensitising studies' to help scope out a design space and develop initial design concepts. Sensitising studies are generally shorter and aim to 'shed light on' particular problems that research could address. By observing a family organising a day out, the team were able to gain an understanding of the activity they would be designing for. It did not tell them what to build, but instead allowed them to see the scope of the design and they areas in which they could intervene.

Some of these uses will be discussed later when looking at case studies of ethnography in design.

Technomethodology

Button and Dourish (1996) describe the use of ethnomethodologically informed ethnography for technological support of socially-organised activity as 'Technomethodology'. They describe the *paradox of technomethodology:*– how can ethnomethodology be applied to the design of new technologies given the concern that is has for details? Thus they question how people can learn from this within a design context. They describe three potential models:

Learning from the ethnomethodologist

Here the ethnomethodologist is the primary resource in the design process by working closely with the designers after spending time in the field. Therefore the ethnomethodologist becomes a proxy for the field setting itself.

Learning from ethnomethodological accounts

Here the main focus is on the ethnomethodological accounts of a work setting. This will also probably involve close collaboration with the ethnomethodologist but the designers work from an account of this, rather than directly with the ethnomethodologist. However this relies on the designers being well versed enough in ethnomethodology to understanding the account that is provided.

Learning from ethnomethodology

With this approach there is a more theoretical relationship that looks towards a hybrid discipline where "design adopts the analytic mentality of ethnomethodology, and ethnomethodology dons the practical mantle of design" (Button & Dourish, 1996, p. 22). It looks at the contrast between the use of abstractions in systems design and the representations of activity from an ethnomethodological perspective. The authors propose the notion of 'accounts' as computational representations that systems continuously provide of their own behaviour and activities, which can be used as a resource for improvised and contextual action. This computational accountability therefore relates interface activity to the underlying structure below this.

Systems design is fundamentally focused on the creation, manipulation and use of abstractions whereas ethnomethodology has an overriding focus on the particular details of practice. This creates a conflict. This third perspective attempts to restructure the design process so that it is more aligned with the details of how working practices arise and are constituted.

'Implications for Design'

Papers that report results from ethnographic studies will often close with a section titled 'Implications for Design' and this is often seen as a major evaluation criteria of the technique (Dourish, 2006). Dourish states that informal evidence suggests that the absence of such a section tends to correlate with negative reviews and rankings of papers. Yet he believes that this focus is misplaced and misrepresents the nature of ethnographic work. He also believes that it misses out on areas where ethnography can provide major insights for HCI research.

The Marginalisation of Theory

Ethnography was brought into HCI research in response to the perceived problems of moving from lab studies to gaining broader understandings of organisational settings and their use of technology. Initially this was a case of bringing ethnographers to HCI research. Thus the focus in its definition is on the fact that the ethnographer goes into the field, observes, returns and reports (Dourish, 2006). This view of ethnography as purely methodological supports the view that the primary output of the process is implications for design. However this view obscures the theoretical and analytic components of ethnographic analysis. As stated previously, it is a means of understanding the member's experience, but it does not simply involve reporting this. It also theorises its subjects. It is an interpretative process that sets out to explore relationships between observations and also looks at how member's experiences can be understood as interplay between the members and the ethnographer. In fact, even within ethnomethodology which "*rejects sociological theorising in favour of explicating observable practices*" (Dourish, 2006, p. 543) this is still the case as the theories presented are the subject's own.

Thus, ethnography perhaps should not only be perceived as being a process that feeds into design, but as something beyond this.

Ethnographers or Natives

In a design context the 'ethnographer is a surrogate for the domain'. However, no matter how competent the ethnographer, they can never know the domain as users know it. Therefore it may be questioned why an ethnographic account is required, when domain or context insiders could provide this? But the issue here is that users often find it hard to articulate what they know, as it is not easily summarised and decontextualized. Additionally, they have their own interests and concerns, as a result of the wider organisational structure that they are part of. The knowledge needs bringing out and directing towards the concerns of the design. Thus the ethnographer is someone knowledgeable about but distanced enough from the domain (Hughes, Randall, & Shapiro, 1993).

Hughes, Randall, and Shapiro (1993) point out that the ethnographer is an 'incompetent' in the culture and thus can ask the naïve questions that experts would not. The fieldworker can't be expected to acquire the knowledge of the domain to the extent of those who populate it. Indeed to do so too much would mean 'going native' and thereby losing the analytic and theoretical attitude. A non-native perspective is required in order to properly analyse and interpret what is being seen.

In fact the issue of 'going-native' is highly important, as through growing familiarity of immersion in the domain, an ethnographer will become less sensitive to the how and why of what is going on (Hughes, Randall, & Shapiro, 1993). It is important to maintain a balance between being a complete outsider and a native. It is important to understand enough of the context to be able to understand and identify the details of the work, but without getting caught up in the process of 'doing it' as a native might. Periodic distancing is a useful means of achieving this.

Summary

This section has provided an overview of the potential uses for ethnography and ethnomethodology and the ways in which it can be used to inform design, as well as the possibility of developing a hybrid discipline between these. There are many debates that exist in this area as to exactly what ethnography is, and how it should be used. What is clear is that it serves as a potential tool in understanding, analysing, and representing the context of work and is a key approach to be considered in this research. However, in addition to these higher-level perspectives, there are a number of practical considerations to take when carrying out ethnographic work, such as how to generate requirements and ways to represent findings.

3.5.6 Ethnography and Requirements Engineering

As Viller and Sommerville (1999) state, the enthusiasm for the results of ethnographically informed design has been balanced by a frustration with accessing and making use of these results in design. Finding ways to represent the results so as to be useful to system developers has proved to be a challenge, and there are many examples of techniques to try and address this.

Fieldworkers construct their own ethnographic record as an 'aide-memoir' which allows them to later recall their work. However, when it comes to a tool for presenting this information to others, it has little use.

Figure 13 shows the ethnographic notes created during this research and it is clear that a software developer would not be very pleased at having to sift through this when creating a requirements document. Instead it is important to create an additional means of recording and representing this information for communication with developers.

Figure 13 - Ethnographic Record

The key challenges that arise from this are described by Viller and Sommerville (1999) as follows:

- ***Time:*** Ethnography is traditionally a much longer process than the requirements engineering process.
- ***Results:*** Ethnography generates detailed textual descriptions making communication of these findings challenging.
- ***Culture:*** There are significant differences in culture and language between ethnographers and software developers.
- ***Abstraction:*** It is difficult to draw abstract lessons from a technique concerned with details.

Hughes, O'Brien, Rodden, Rouncefield and Sommerville (1995) propose three viewpoints that may help ethnographers to structure and bring out the key aspects of the work that they have studied. These are as follows:

- *The setting of work:* This is often reported in terms of the physical layout and it seeks to represent the spatial distribution of the workplace, its participants, the work they do, and the resources that they use.
- *Social and organisational perspectives of the work:* This viewpoint represents the real world, real time nature of work. This is often presented as illustrative vignettes within a larger discursive presentation of material.
- *Workflow:* This viewpoint focuses on sequences of work activities and information flows. It seeks to emphasise the division of labour and any interdependencies within this.

In order to represent these viewpoints more formally, the authors used a hypertext design rationale tool to record them. This involved the creation of viewpoint windows displaying a collection of observational material linked through an abstract and cross-referenced model. Figure 14 displays an example of this.

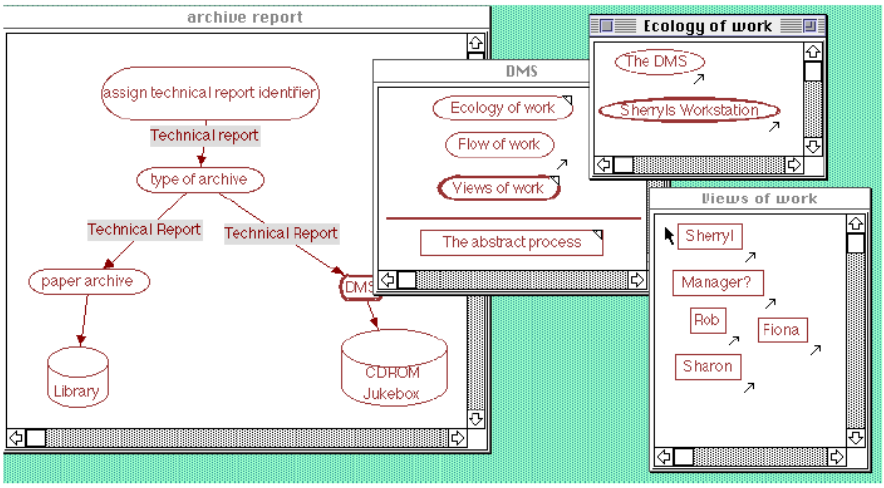

Figure 14 - Representing Viewpoints (Hughes, O'Brien, Rodden, Rouncefield, & Sommerville, 1995)

Later the authors proposed a framework for presenting findings based around the following dimensions:

- *Distributed Coordination:* referring to the patterns of activity within which tasks are performed.
- *Plans and Procedures:* the means through which distributed coordination is supported. This includes project plans and schedules, instruction manuals, job descriptions, organisational charts, and workflow diagrams.
- *Awareness of work:* the way in which the organisation of work activities is made visible or intelligible to others. These are the practices for enabling people to have an awareness of the work that is being done.

(Hughes, O'Brien, Rodden, & Rouncefield, 1997)

Over time further work has been carried out within this area, and as software development methods and tools have changed, so have the ethnographic representations.

As previously discussed, requirements have a fundamental role in systems and software engineering, as a way of formally representing a proposed design. Converting ethnographic findings into requirements can be challenging for the reasons stated above.

Viller and Sommerville (1999) discuss the Coherence method, which aims to assist the process of generating requirements specifications through an ethnographically informed approach to requirements engineering. Here the requirements engineers carry out the analysis themselves with guidance in the form of a viewpoints structure. They use the PREview structure (Sommerville, Sawyer, & Viller, 1998), which uses business drivers of the requirements elicitation process (or *concerns)* to assist the analysis of how a system could best serve an organisation. In PREview, a viewpoint consists of a name, focus, concerns, sources, requirements, and a history. It also defines a process in which *concerns* are first identified and then elaborated through a set of questions, and finally the elicitation of requirements. Concerns are identified at the outset of a project through discussions with stakeholders. These cut through viewpoints as they may constrain any requirement (such as the concerns of 'safety' or 'compatibility'). Coherence structures its viewpoints around the presentation framework developed by Hughes, O'Brien, Rodden, and Rouncefield (1997) (as discussed above).

Within these three dimensions, Coherence provides a number of questions to help elaborate on them and in turn a number of questions are provided to elaborate on concerns. An example question on a viewpoint may be 'how is the division of labour manifest through the work of individuals and its coordination with others'. A *concern* question may be 'how do forms and other artefacts on paper or screen act as embodiments of the process'. By setting out to answer these questions, someone without a background in sociology or ethnography can begin to carry out a social analysis.

Coherence also uses Unified Modelling Language (UML) to communicate its results. When UML was being introduced within the domain of software development, Viller and Sommerville (1999) looked at an approach based around this representation. They wanted to examine how UML (for object oriented design) could be used to express information about awareness in cooperative systems.

They tested the method in a case study at a Training Centre Office responsible for the operation of a Management Training Centre. One of the examples of use they discuss is a means of representing peripheral awareness (an alertness to what is happening around a person while they work, whilst selectively attending to events that may be relevant). In this company coordinators used the distinction between phone rings tones to help them know whether phone calls were from outside or inside the company. This was represented by using a constraint as seen in Figure 15. They were also able to represent awareness of history (using stereotyped associations), informal annotations on bookings paperwork (through the use of comments and a scanned image), and business rules (as a constraint).

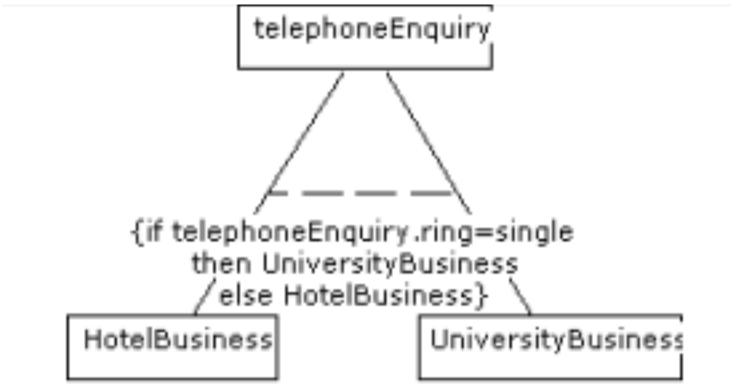

Figure 15 - Using a Constraint to Represent Peripheral Awareness (Viller & Sommerville, 1999)

Through making use of extension mechanisms within UML the authors were able to represent typical information gained through ethnographic studies. In the worst-case scenario, a comment can be used (as was done with attaching scanned paperwork). The authors therefore feel that UML is a flexible enough tool to represent this type of information but that it should be used within a process that provides guidance so that designers can use the ideas themselves (such as 'pay attention to issues of awareness in work') (Viller & Sommerville, 1999).

Summary

This section has demonstrated the challenges that can arise in representing ethnographic accounts in a more formal manner that can be used by systems developers. Due to the individual nature of this thesis research, this was not a primary challenge as the person that carried out the ethnographic work also generated the requirements. In addition to this, the requirements were an aid to the design process, and not a crucial means of communicating the ethnographic findings to others. Yet this is a procedure that should be considered carefully when carrying out this type of work in the future, as it is likely that more than one person would be involved in the design process.

3.5.7 Examples of Ethnography in Design

Over time ethnography has become an accepted method in systems development (despite the continued existence of many debates). A number of researchers have used the method and reflected on its use, suggesting refinements and particular roles that it can play. The following section will provide a selection of case studies of the use of ethnography.

Ethnography in Contextual Design

This first example is a description of Simonsen and Kensing's (1997) study of a design project carried out at a film Editorial Board where the authors examined the use of ethnography within contextual design by comparing it with more traditional approaches.

The project was carried out in two parts. The first phase used techniques such as meetings, unstructured interviews, and document analysis to produce an initial design proposal. The second phase looked at using ethnographic techniques such as observation and video recording. The effect of this was then evaluated against the original design proposal.

Phase One – Traditional Design

As already stated, this looked at more traditional approaches. The output of this stage was presented in the form of rich pictures and mock-ups that were presented to the Editorial Board and its technology committee. Through this they presented two preliminary mock-ups that the board deemed to be very appropriate. In normal circumstances the team would have begun refining and prototyping the proposal. However, in order to assess the value of ethnographic techniques, a further design stage was carried out.

Phase Two – Ethnographic Techniques

The design proposals from stage one primarily supported the work of the secretaries, production manager and consultant, whose jobs are to support the editors. In this second phase observations were carried out of the editors work, which until this time was complex and invisible to the rest of the organisation. This primarily involved following them for a few days in their offices and in the field. The observations were videotaped and replayed during discussions between the research team. Questions that arose during these discussions were followed up with interviews with all employees, focusing on the cooperative nature of the work. In order to build on this picture, wall graph sessions were also held.

Wall Graph Sessions

Simonsen and Kensing (1997) carried out 'wall graph sessions' where they detailed the flow of work from an employee's perspective. Stakeholders were asked to write the activities and functions on the graph. Below this they then added any related data and information. This was all carried out on a single piece of paper with the process and activities mapped across it. Coloured writing was used to distinguish contributions from each participant. The aim of the sessions was to allow the participants to realise the complexity and cooperative work involved in the work processes. It was then able to serve as a point of reference in later discussions.

Interviews were then held with the secretaries focusing on more concrete aspects of the design such as system data and screen layout. Observations of other systems in use at another institution and discussions with the developers of this system also occurred.

Having carried out the second, ethnographically informed, design phase, the team identified a number of key issues that impacted on the final design proposal. For example there were differences in how work was perceived by different stakeholders as well as power struggles between others. Through this they were able to make key changes to the design such as providing more support for editorial work, rather than production work and allowing the design to be portable as the editors are frequently working elsewhere. Their different findings highlighted the potential differences across stakeholder viewpoints and the importance of observing all of these.

Comparisons & Observations

Reflecting on the use of ethnographic observations the authors state that they generated questions to be followed up in interviews, as well as providing a qualitative background for these questions. The interviews became substantial discussions that could allow issues to be conceptualised in detail. The second phase of the design (3 months) was significantly longer than stage one and this allowed the development of insights, consideration of design possibilities and discussions and reflections on these.

The authors state that two lessons have been learned through this work. Firstly that designers may have to observe users during everyday activities to build a shared understanding of current work practices and develop realistic future visions. Secondly ethnography can unveil users' multiple viewpoints (which may need to be integrated into the final system).

As a result of this work Simonsen and Kensing recommend the following preconditions for ethnographic work:

- The designers and the user organisation must have a positive attitude towards investing needed resources, and these resources must be available.
- In order for users to accept and participate they must be confident with the overall purpose of such an approach (i.e. that the aim is to support them, rather than reduce or replace their function).
- The designers must have the competencies to conduct such an approach and handle the situations that may arise.
- The designers and the user organisation must be able to identify potential domains in terms of work practices, where applying resource demanding ethnographic techniques seems appropriate in relation to system design.

(Simonsen & Kensing, 1997, p. 88)

The Different Roles of Ethnography in Design

Hughes, King, Rodden, and Anderson (1994) reflect on work across a number of different projects, and discuss the way in which they integrated ethnography into the system design process. What follows is a discussion of two of these methods and projects they were applied to.

Concurrent ethnography

This is one of the most common uses of ethnography in design and is concerned with investigating the domain prior to the development of the system. The authors used this method when working with the London Air Traffic Control Centre (LATTC) during the development of a prototype for control. They used a process of fieldwork > debriefing > prototype iteration > fieldwork which was repeated around four times until the team felt that little more could be gained by carrying out more fieldwork. Each stage of the fieldwork was directed at issues raised by the designers during debriefings. It must be noted that this was a research project aimed at evaluating prototypes rather than the development of an actual front line system, thus issues that may have arisen during development would not have been encountered. The team was also small, meaning that communication between the sociologists in the field and the computer scientists could be done informally.

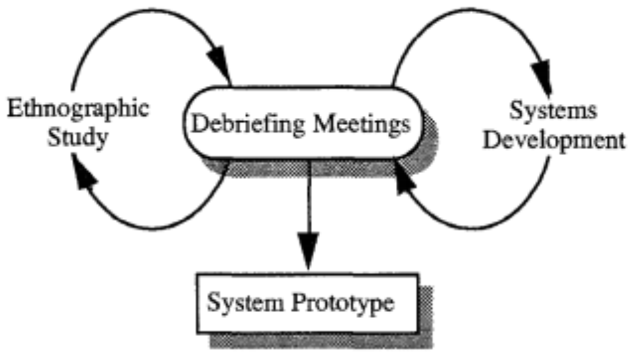

Figure 16 - Use of Concurrent Ethnography from Hughes, King, Rodden, and Anderson (1994).

The ethnography provided a useful insight into the subtleties of the control work and the routine social interactions between the team members. Insights such as the need to retain some of the functionalities of the paper based system in order to keep the controller 'geared into' the work was discovered through the ethnographic work. The team discovered that as the fieldwork continued it had a declining rate of utility in terms of contribution to design. Instead the final fine-tuning of the design needed to be informed by experts actually using the prototypes. Whilst there was potential for more to be learnt from the fieldwork, the payoff was greater during the early stages of ethnography.

Quick and Dirty Ethnography

The term quick and dirty does not have to imply a short period of fieldwork but is instead a reference to its duration relative to the size of the task. The aim is to collect relevant information as quickly as possible, whilst acknowledging that it is impossible to gather a complete and detailed understanding of the domain. However areas can be selected that have a particular importance to the design. Compared to concurrent ethnography, which is much more focused, valuable knowledge of the social organisation of work in a relatively short space of time can still be achieved. Overall it provides an important broad understanding that can sensitise designers to key issues that have a bearing on the eventual acceptance and usability of the envisaged system, rather than on specific aspects of design (Hughes, King, Rodden, & Anderson, 1994).

The authors firstly reflect on using quick and dirty ethnography in the design of a support tool for software engineers. This tool's eventual aim was to display the rationale behind their design choices and thus improve the quality of the system being developed and its maintainability. This is particularly salient to the project discussed in this thesis as collaboration in software engineering is being studied. The project discussed by (Hughes, King, Rodden, & Anderson (1994) wasn't as successful as anticipated but they were still able to make valuable reflections on the process.

For example they encountered some difficulties finding projects to work on that were just starting their development trajectories, as most had already begun. They also had problems working in the constraints of industrial settings. For example one project was cancelled and access to another was difficult due to a '*less than enthusiastic'* gatekeeper who had reservations about their team being studied when under pressure. These issues are both understandable, but illustrate the problems that might arise when carrying out fieldwork in an industrial setting. It also highlights the importance of being accepted into the setting, and being able to deal with real world contingencies. However, despite the difficulties encountered, they were able to understand the 'real world' phenomenon of the design process, and were able to realise that the original design concept was wrongly conceived. The tool would only be effective if used consistently by team members, yet in the conditions in which they worked, this would be too much of an overhead.

"Also, given the personal and company investment in CASE tools of various kinds, persuading engineers to learn and use 'yet another bloody tool' when they were already less than enthusiastic about their current ones, would have been a mammoth task" (Hughes, King, Rodden, & Anderson, 1994, p. 433). This is yet another example of barriers to technology introduction in industry.

The authors also reflect on using this approach to study a team of around 100 software engineers working on avionics systems for a new kind of aircraft (again a salient topic for this thesis). They found that a strict Process Model was in place that was highly constrained and document driven. It was also implemented under tight budgetary constraints. The highly constrained nature of the plan meant that the engineers frequently made various 'fixes' in order to make sure that they got the work done. In addition to this, social and interactional issues were constantly addressed with the aim being to improve the efficiency and quality of the work. For example, whilst being studied the team was reorganised in an effort to improve communications and sharing of experience and skills. Team building exercises were also run by management.

Another problem that arose in this case study was that of communicating the findings from the ethnographic work to the designers. This was in part due to the increased scale of the setting. It was also difficult to pin the findings to clear design objectives.

Summary

These examples provided are very useful in highlighting both the benefits of using ethnography and the different roles it can play in design, as well as the practical issues that can occur. What is of particular interest is that two of the studies mentioned by Hughes, King, Rodden, and Anderson (1994) were based within a software engineering environment. Therefore the lessons learnt from this should be noted carefully.

Hughes, King, Rodden, and Anderson (1994) reflect on a number of lessons learnt during their studies:

- *A variety of roles for ethnography in design*. Designers require information at many different phases of the design process and ethnography can play a role during a number of these, making different contributions to each of them.
- *Responding to pressure of time and budget*. Ethnography is often perceived as a prolonged activity but it can also be useful when used for relatively short periods of time. With design, diminishing returns to fieldwork can set in relatively quickly.
- *The importance of focus*. Focus is a key factor in the success of ethnography. When the authors studied an air traffic control room, the room itself was a clear natural focus. However in larger studies with no single location more problems were observed as no single place could provide a complete insight into the work processes.
- *The importance of previous studies*. Building an accumulation of studies is vital so that there is a body of work for people to refer to. Most early CSCW studies did not have this. This raises the question of how a corpus of studies can be made available to software engineering and those involved in the design process.

(Hughes, King, Rodden, & Anderson, 1994)

3.5.8 The Practicalities of Ethnography

Most of the studies mentioned previously have been reflective rather than specifying a particular approach to the details of ethnography. However some attempts have been made to describe the process and how it should be carried out. This section will discuss in more detail the types of techniques and processes that can be used when carrying out ethnography for the purposes of systems design.

Crabtree (2003) feels that it is important to go into the field with open eyes, rather than being blinkered towards certain phenomenon. However, as a result of this, it can be difficult to establish where to start the research. Although trying to avoid being too prescriptive, Crabtree (2003) sets out a number of phases to guide this ethnographic work.

Exploration

As Crabtree (2003) states, there are no fixed procedures to this phase of work. It will vary depending on the nature of the work under study as well as the particular context of the organisation or environment. Therefore pretty much any ethically sound method can be used to collect data. "*Just how the researcher goes about developing an intimate familiarity with the site's work is an open question to some extent, the limits of the extent being that they develop a thoroughgoing familiarity with what goes on without upsetting, offending, or jeopardizing the careers of parties to the work*" (Crabtree, 2003, p. 50). The researcher is simply getting to know the work or activities that are being undertaken.

Inspection

Over time, during exploration, certain activities will capture the attention of the researcher, becoming more pronounced (Crabtree, 2003). Themes may also begin to emerge. Inspection involves looking at these areas and themes in more detail, to further understand the emergent categories of analysis. The researcher needs to assemble instances of the activities, to examine them in more detail. The primary unit of analysis at this stage is the workplace activities actually being carried out. This may involve a number of visits, and re-visits to the site, looking to fill in any gaps in knowledge. Crabtree has strong opinions about this stage of the work stating that gaps should be addressed in this manner rather than the *"standard academic practice of filling gaps through generic analytic formats….It might be said that if the researcher finds themselves in a situation of using generic analytic formats to interpret just what's happening and how – that is, of guessing, no matter how erudite the form – then they are going off track"* (Crabtree, 2003, p. 52).

Materials & Artefacts

In order to carry out inspections, materials must be gathered. This may include notes taken on what is done, heard and overheard, sketches, diagrams, photographs of spaces, the arrangement of artefacts, photocopies of documentation, video or audio recordings activities. Some examples are as follows:

- *activity or job descriptions*
- *rules and procedures said to govern particular activities*
- *descriptions of activities being done*
- *recordings of the talk taking place between parties to the actual doing of activities*
- *informal interviews with participants elaborating particular activities and the skills, competences, troubles, and practical solutions involved in getting them done.*
- *Diagrams of the material arrangement of the space and place within which staff are located and related, and the arrangement of artefacts therein*
- *Photographs of artefacts (documents, diagrams, forms, computers, etc.) used in the course of activities actually being done*
- *Videos of artefacts in actual use (how artefacts are actually used in getting work done).*
- *Workflow diagrams delineating the sequential order of tasks involved in the actual doing of particular activities.*
- *Process maps delineating sequential connections between activities.*

(Crabtree, 2003).

Recording
Crabtree also discusses the importance of recording *"One of the most important pieces of equipment in the ethnographers toolkit is, without doubt, the notebook in which everything the ethnographer thinks is worth recording is initially put down"* (Crabtree, 2003, p. 54). This can include 'random jottings', about areas of possible interest, parts of conversations, and sketches, but over time these should become more detailed, structured and coherent.

This discussion on recording is important. Whilst often it is possible to make audio recordings of observations, discussions, and interviews, this is not always viable in industrial settings for privacy reasons. Therefore the use of a notebook becomes even more important. It also serves as a single point of reference for ideas.

Gatekeepers
Hammersley and Atkinson (2007) discuss the concept of gatekeepers in ethnographic work. These are key personnel who can grant or withhold permission for research activities. Whilst the gatekeeper role is vital, it can also have a great influence on the data collection process. For example they may point a researcher towards things they think are interesting, whereas the mundane is also of interest. It is worth noting that, according to Hammersley and Atkinson (2007) "whether or not they grant entry to the setting, gatekeepers will generally, and, understandably, be concerned as to the picture of the organisation or community that the ethnographer will paint, and they will usually have practical interests in seeing themselves and their colleagues presented in a favourable light."

Summary
Ethnography is not a highly prescriptive process, as the researcher needs to be flexible enough to fit their techniques to the context that they find themselves in. However, Crabtree proposes a process of initial exploration followed by closer inspection of areas that have come to the attention of the researcher. This may involve assembling instances of activities and studying artefacts. It is also important to consider the practicalities of recording data and gaining access to people through roles such as Gatekeepers.

3.5.9 Ethnography Summary
This section has highlighted the important role that ethnography (and ethnographers) can play in the design process. By understanding the domain as a member would, they can advise on the 'accountable' nature of activities and provide guidance to the design team.

Through looking at 'lessons learned' on particular projects, and more detailed guidance of the ethnographic process it is possible to see that ethnography can be an unpredictable process, with the need for the researcher to remain flexible at all times. Thus guidance such as that provided by Crabtree is necessarily vague. However, these are all key considerations that were taken into account during the studies at Airbus.

3.6 Involving Users in Design

As well as carrying out fieldwork and ethnography, where users are observed and interviewed, it is also possible to involve them more directly in the design of technology and work. Participatory design (PD) is an approach to bringing users and other stakeholders into the design team at different stages of the design lifecycle (Muller & Kuhn, 1993). By treating users as co-designers, their knowledge and experience of the domain can be fully utilised when considering the future use of technologies in their work.

3.6.1 Participatory Design

Participatory design is based around the belief that if an individual is involved in the design of a system, they are more likely to help produce a product that they consider to be useful. It gives employees the chance to exert influence over their environment and also provides empowerment in the form of increased responsibility during the design process.

“The original PD processes were not organised in cooperation with companies who developed technologies, but rather through government organisations and workers’ trade unions....Through engaging end users (not necessarily ‘consumers’) in technology design processes, technologists gained a better understanding of the work their products were developed to support, and not surprisingly, better products resulted” (Buur & Matthews, 2008, p. 186).

The PD approach aims to involve all users of the system from managers to operational staff in the development of the system (Avison and Fitzgerald, 1988).

Mumford’s three levels (described by Avison and Fitzgerald (1988)) are as follows:

Consultative Participation: This will involve group discussion with the users where the new system can be discussed and the users can put forward any suggestions they have. However, the main design is still principally the job of the systems analyst. This level of participation is in fact part of the conventional approach to design and does not wholly constitute participatory design.

Representative Participation: This is likely to involve design groups consisting of users and developers where both parties will have an equal say in the decisions made. In this set up, the users selected to be part of the design team will be representing their colleagues.

Consensus Participation: This attempts to involve all affected staff in the design process so that decisions being made are taken by the staff as a whole. This approach may cause the decision making process to be much slower (Avison & Fitzgerald, 1988).

3.6.2 MUST Method

Kensing, Simonsen, and Bødker (1996) present a method for participatory design in an organizational context. This is focused on designing for a specific organisation's needs rather than introducing existing 'generic' products. When referring to design they state that they are focusing on "the analysis of needs and opportunities, and the preliminary design of functionality and form" (Kensing, Simonsen, & Bødker, 1996, p. 129).

The MUST method was developed across 10 projects in Danish and American organisations. The processes being studied included the editorial board of a film company (Simonsen & Kensing, 1997), people at an R&D lab and also a radio station. The design project agendas in all these settings were very open ended, with no clear problem statement or idea of the kind of IT support needed.

MUST is a method for supporting early design activities before a contractual bid takes place (when introducing new/generic systems) which aims to minimise the risk of introducing unrealistic or inefficient systems. It deals with a number of activities such as analysis of needs and possibilities, generation of visions for change, project management and planning for technical and organisational implementation. It is important to note that the actual development and implementation of the system is outside the scope of this method. The results of this design project will be a conceptual design including written documents, sketches, mock-ups and prototypes.

The MUST method is of particular relevance to this research, due to its focus on Participatory Design in industry, as well as early design activities such as identifying needs and possibilities.

6 Principles of the MUST method

1) *Participation* – a way of increasing the chances that a design will correspond to the real needs and will be used as intended. IT experts need knowledge of the use domain and the users need knowledge of the technical options available to them.
2) *Close links to project management* – The design team consists of IT professionals and users and a steering committee consisting of managers of involved units and further user representatives. The steering committee is responsible for supervising the project, dealing with conflicts and making decisions based on information provided by the design team.
3) *Design as a communication process* – There are three domains of discourse (users' present work, new system & technological options) and two levels of knowledge (abstract and concrete). The communication process between IT professionals and users needs to allow them to jointly develop knowledge within all six of these areas.
4) *Combining ethnography and intervention* – applying a combination of ethnographic techniques and intervention (deliberate activities designed to change the organisation) in an iterative approach to design. This tries to avoid an extremely futuristic design by reducing the role of formalisms, and instead focusing on plain text, freehand drawings and sketches.

5) *Co-development of IT, work organisation, and users' qualifications* – Projects often focus on IT systems rather than organisational implementation. Additionally systems are often only partly used as users have not been properly introduced to them (as seen by Orlikowski (1992)). The design team should consider the education of users and how this will be organised.
6) *Sustainability* – a high degree of user participation is needed so that new IT systems fit with preferred working practices, whilst also supporting the organisation in dealing with conflicts relating to the introduction of IT systems.

The MUST method also proposes five main design activities. This process should be iterative. The final activity (anchoring the visions) should be considered as an on going concern throughout the project.

Project Establishment
It is important to establish and clarify the aim, level of ambition, scope and conditions of the project. This includes the team deciding which tools and techniques will be used.

Strategic Analysis
It is important to identify which work domains should be in focus during the project. This stage sets out to clarify the potential for investment in IT projects and the organisational, economical and technical limitations of this. It looks at which parts of the organisation need to be strengthened from a strategic perspective. This is seen as primarily a management activity.

In-Depth Analysis of Selected Work Domains
The purpose of this design phase is to explore the domain(s) selected during the strategic analysis to uncover the rationale behind work activities. The rationale is key as the team don't want to simply map old practices into the new system. The techniques used in this phase may include interviews and observations with users who will be affected by the changes, analysis of documents used in the work practices, think aloud sessions, mapping, future workshops, and workshops where the design team and users make rich pictures, collages and wall graphs (see (Simonsen & Kensing, 1997)) of current work practices.

The results of this will be descriptions of the current work practices and organisation and the related problems, needs and ideas for IT support. This output also has the added bonus of allowing the users to see their work in a new light.

Developing Visions of the Overall Change
This is the central activity of the MUST method. The visions should include the functionality of the system but also the changes in the organisation and user qualifications that will be needed. Activities undertaken during this stage may include visits to similar workplaces using new IT systems, further future workshops, design workshops where the design team and users sketch their envisioned future work organisation along with the IT facilities', data modelling, and prototyping.

The result of this stage is a design report that states the aim of the project, summarises the analysis, and describes the proposed visions. This may include the mock-ups and prototypes and also scenarios of how the work will be carried out once the vision has been implemented. It should also include an evaluation of the positive and negative consequences of the visions, estimated costs and plans for implementation and training.

The report can then be used by the steering committee to make decisions on which vision should be implemented, along with which parts will be developed or purchased as generic systems.

Anchoring the Visions

The design needs to be 'deeply rooted in the organisation' and therefore the rationale behind it needs to be understood by the management and steering committee, the users, and those that will carry out the implementation. As these people may not all be involved in developing the visions, efforts should be made to familiarise them with the visions. Activities used for this may include meetings and workshops to present design ideas, prototyping, demos, and scenarios describing future work practices.

Summary

The concepts and processes described in the MUST method go beyond what may often be perceived as Participatory Design. It draws in techniques such as ethnography, Future Workshops, Scenario generation and more technology demos. As has previously been stated, the focus on early design is key, particularly the recognition that the context needs to be explored in order to establish 'needs' and 'possibilities'.

3.6.3 Potential Problems with Participatory Design

One major problem with PD is the culture. The PD approach was developed and is widely used in Scandinavian countries where the culture is more attracted to working as a group to solve problems. However, in the UK and US where culture can be more individualistic and companies are more likely to have a structured and hierarchical structure, this may be less successful. Managers may be more reluctant to give the level of power required for PD to employees lower down the hierarchy, and employees may feel that it is not their responsibility due to the presence of technical staff (Mumford, 1997).

It may be that when trying to use this technique within a UK company, there is less enthusiasm towards it. However, as time goes on such practices are becoming increasingly common and more accepted.

3.6.4 Summary

Participatory design is an important process for ensuring that users have a detailed say in the way that systems that they will be using are designed. There are various ways in which this can happen, ranging from consulting users to working directly with them as co-designers. Additionally, the involvement may be from a representative set of users or all of them (consensus participation). In general, within development practices today, it is the former option that is utilised most as it is much quicker and easier to orchestrate. This section has also introduced the MUST method, which integrates PD practices into a much wider design practice.

3.7 Introducing Technology

As has been shown previously in this literature review, the use of tools is a human trait. People often create tools to satisfy their needs. In order to create or find technology that meets these needs, they need to be specified in a more explicit and formal manner. This will then guide efforts to develop or find technology to meet the needs. Once this process is complete, the technology can then be introduced into the workplace. However, introducing technology into a workplace can be challenging and may have a great impact on the way in which people work.

"Designers are seen as change agents seeking to push existing boundaries and develop new alternatives to the status quo. Business people, on the other hand, are often deeply invested in the status quo and uncomfortable with shifting away from it without careful consideration and a high threshold of proof." (Martin & Riel, 2010, p. 18).

3.7.1 Socio-Technical Perspective

At the beginning of the twentieth century, the perception of technology was that users and organisations needed to adapt to technological advances (Dix, Finlay, Abowd, & Beale, 2004). Information technology was seen as an external force to the organisation that could shape its structure, with people needing to adapt to and accommodate it.

The socio-technical perspective is concerned with the impact that systems can have on both individuals and the organisation (Cadle & Yates, 2004). This approach to design became popular after WWII when a group of social scientists formed the Tavistock Institute of Human Relations in London. The original motivation behind the Institute was to apply perspectives from the areas of mental health and individual development to workers in industry, with the aim of making groups aware of the emotional factors that could hinder performance (Mumford, 1997). However, they were also aware of the impact and influences of technology in workers and their well-being, and set out to promote optimisation of both the social and technical implications of systems within organisations.

This perspective has persisted and it is generally recognised that when introducing technology into industry, its impact on the organisation and workforce needs to be considered carefully. The next sections will look at examples of problems that may occur within an organisation when introducing technology. This will focus on collaborative technology, as not only is this a particularly challenging area, it is also the focus of this thesis.

3.7.2 Introducing Collaborative Systems

Despite the benefits offered by collaborative systems, there are also a number of challenges associated with the development and introduction of these systems that can often lead to failure.

“Repeated, expensive groupware failures result from not meeting the challenges in design and evaluation arising from these differences.” (Grudin, 1994, p. 93)

The problem with CSCW applications is that they must adapt to the organisation, fitting into existing work practices and appealing to everyone who must use or support it (Grudin, 1994). To add to this, they still have all the interface design challenges of single user applications.

Grudin (1994) cites a number of problems, drawn from development experience, descriptions of short-lived products and research prototypes, and experimental and modelling studies in the literature:

1) *A disparity: work vs benefit:* Groupware applications often require additional work from individuals who do not receive direct benefit from the use of the application. As a result of this, it is important to try and create benefits for all users.
2) *Critical mass and Prisoner’s dilemma problems:* Groupware may not achieve the critical mass of users required to make it useful, or fail because it is never to one individual’s advantage to use it.
3) *Disruption of social processes:* Groupware can lead to activity that threatens existing social and political structures.
4) *Exception Handling:* Groupware may not accommodate the wide range of exception handling and improvisation common in many group activities. It is difficult to determine the actual standard procedures to support, especially in unpredicted situations. It is also important to focus on how work is really done, rather than how it should be done.
5) *Unobtrusive accessibility:* Not all groupware features may be used heavily, but nonetheless still need to be supported. This support must be well integrated with more frequently used features.
6) *Difficulty of evaluation:* It is difficult to learn from experience with groupware, due to the obstacles to meaningful, generalisable analysis and evaluation of it. Group observations are complicated by the number of people involved over time and space, and the fact that group interactions often unfold over days or weeks.
7) *Failure of Intuition:* Intuitions in product development are particularly poor for CSCW applications.
8) *The adoption process:* Groupware requires more careful implementation and introduction into the workplace than previously confronted.

Distributed Knock on Viscosity

Distributed knock on viscosity (Rogers, 1994) describes the additional activities that users are required to perform as a result of a new system, but that are extraneous to their own goals. This may occur if a system is configured so that another person is able to carry out their work in a more efficient manner.

Gradient of Resistance

These are the problems that designers face when making changes or adding new features to a system (or prototype) together with the need for varying levels of legitimacy, to justify the acceptance of these changes. “The deeper the gradient of resistance, the more fixed the design; hence the more difficult it is to make changes to the prototype or system that is being designed" (Rogers, 1994, p. 69). For example, with a very established set of working practices, there may be a great deal of resistance to changing it. Yet also, the more radical the change is, the more resistance there will be (Rogers, 1994). This appears to be of greater importance with CSCW systems.

What follows is two case study based descriptions of the introduction of groupware, and the issues that can arise during this. Some of these are linked to the collaborative nature of the system, and others are more general. Both of these case studies link to the introduction of existing technology.

3.7.3 Case Studies of Groupware Introduction

Introducing Lotus Notes

In order to understand the changes required in work practices as well as the social practices that it could facilitate Orlikowski (1992) explored the introduction of groupware in a large services firm. The technology in question was Lotus Notes (a multi-user client-server cross-platform for supporting collaborative tools such as email and shared calendar). Orlikowski wanted to see how this tool was adopted and used and how it changed the nature of work at the organisation as well as the patterns of social interactions. The following issues were highlighted through this work.

'Top-Down' Introduction

Orlikowski (1992) saw that the company had undertaken an internal study of the firm's technological capabilities, weaknesses and requirements as it was not utilising technology as well as competitors (and client expectations). Subsequently, they developed a Chief Information Officer (CIO) role, responsible for the firm's internal use of technology. The CIO was introduced to Notes when reviewing communication software. He played with notes for a few days before realising that it was a 'breakthrough technology' and it was shortly after this that the CIO announced that the product would be the company's communication standard. To introduce the technology the CIO gave talks to principals and managers, promoting his 'vision', and demand for the tool subsequently grew.

Existing Frames of Reference

"Weakly developed technological frames of a new and different technology are a significant problem in technology transfer because people act towards technology on the basis of the meaning it has for them" (Orlikowski, 1992, p. 364). When an individual is presented with a new technology they will use their existing *technological frames* to try and make sense of it (much like Piaget's theory of Schemas and Assimilation (1932)). If the technology is sufficiently different, they will need to modify these frames in order to accommodate it. This modification will depend on i) the kind and amount of product information communicated to them, and ii) the nature and form of the training they receive on the product.

In this organisation the team received very little information about Notes. In fact some of them only heard about the company's adoption through the trade press, and most encountered it for the first time when it was installed on their work computers. These employees were therefore left to make their own assumptions about the technology. The technological frames around Notes were therefore weakly developed (Orlikowski, 1992).

Training

"*Training users on new technology is central to their understanding of its capabilities and appreciating how it differs from other technologies with which they are familiar*" (Orlikowski, 1992, p. 365). This training can also help to augment their existing technological frames (or the development of new ones if appropriate). In the case study presented, the company decided to throw the technology at users rather than spending a lot of time training them. The CIO believed that with Notes, experimentation was the key to users appreciating the potential of the technology (*user-driven diffusion strategy*). However this can be a slow process and during the short time frame of the case study, no user initiatives around Notes were discovered.

Reward Systems

Within the firm the employee hours were billable and charged to clients. As the use of Notes was not perceived as a client based activity, there was a reluctance to spend time using it. The consultants perceived time spent on Notes to be less legitimate than client work.

Privacy

New technologies can bring issues regarding privacy due to a lack of understanding of tools. In Orlikowski's study, participants found a lack of knowledge about issues such as data quality, confidentiality, access control, and particularly liability inhibited their use of the tool. Principals in the company worried about data security:

"We need to worry about who is seeing the data. … Managers should not be able to access all the information even if it is useful…because they leave and may go and work for competitors. So there should be prohibitions on information access." "*I am not sure how secure Notes is. Many times we have run into difficulties and things have got lost in never-never land."* "*I have concerns about what goes into the databases and who has access to them and what access they have"* (Orlikowski, 1992, p. 366).

Culture

Orlikowski noted conflicts between the company culture and the use of groupware. "*The competitive individualism—which reinforces individual effort and ability, and does not support cooperation or sharing of expertise—is counter cultural to the underlying premise of groupware technologies*" (Orlikowski, 1992, p. 367). It was therefore not surprising to see that in the company being studied, the use of Notes was used largely as an individual productivity tool. However the technologists in the firm, who had less of this culture and individual reward systems, were able to use the tool to exchange technical expertise when solving problems.

Summary

Orlikowski's case study highlighted a number of issues that this company encountered when introducing groupware. One key point is the top down nature of technology introduction in this company. The company took the initiative to create the CIO role, but by cascading information or initiatives down through management, those who actually use the system may have little say. This is a common consequence of introducing CSCW systems. In addition to this, it is important to consider the current frames of reference that people have and how new technology may or may not fit into this. Effective training can help users to see the new potentials of the system, and thus help them use it to its full potential. If not, people may treat it as they would individual productivity tools.

Additionally, the role of company culture towards issues such as rewards and privacy can greatly impact on the ways in which group technologies are used. It is therefore vital to consider these when introducing technology.

Introducing a Multi-User System at a Travel Centre

Rogers (1994) explored a case study of a multi-user system at a travel centre that demonstrates some of the issues of management introducing technology without consulting their staff.

A new system had been selected for the firm by the management, based on demos given to them. The system offered new top of the range features that would assist in tasks such as statistical analysis and financial reporting. However, the directors had evaluated the system based on their own objectives, rather than consulting users or considering how the system could support existing practices. As a result of this, the system actually provided a number of constraints, despite the many new functions. For example, it was no longer possible to make changes to confirmed bookings, which whilst advantageous to accounts staff who could be sure that bookings would not change, travel consultants were forced to delete files and create new bookings when changes needed to be made. This is a key example of *distributed knock on viscosity*, where the jobs of the accounts staff were made easier, at the expense of the travel consultants. This is a common result of focusing too strongly on one perspective of work processes (or failing to consider them at all!).

This same study also highlighted examples of *gradients of resistance*, where the introduction of an automated database for storing the most up to date travel fares clashed with the way in which travel consultants currently managed these data using their own personal paper based files. This new technology, whilst obviously beneficial, required them to change their working practices radically. As a result of this, it was eventually agreed that a more incremental roll out of the technology would take place, allowing a more evolutionary change in work practices.

3.7.4 Overcoming These Challenges

Grudin (1994) lists methods that can help overcome the behavioural and social challenges facing CSCW development and use:

- Add groupware features to extend the use of single user applications i.e. adding collaborative writing features to existing word processors *"Groupware features will fare better if integrated with features that support individual activity"* (Grudin, 1994, p. 99).

- Find ways to provide direct benefit for all group members and be wary of apps that will selectively benefit managers or decision makers.
- Identify a group's problems and match the computer solution to it.

One particularly interesting point that he makes is that people tend to focus on supporting structured processes, which can be inappropriate for communication technologies that best support important unstructured processes. Through gaining an understanding of these unstructured (and often unrecognised) processes, it may be possible to design to support these.

Grudin's final point is vital. It is important to first identify a problem and then 'match' the computer solution to this. This may mean designing the system to support them, or finding technology that already exists.

The reasons why many CSCW systems fail, as demonstrated above, is due to the fact that their design pays little attention to the social context of work, suggesting an inadequacy with existing methods of requirements elicitation and work analysis (Hughes, King, Rodden, & Anderson, 1994).

CSCW systems by their very nature are more complex than single-user systems (Rogers, 1994). Therefore it is important to gain a solid understanding of the different types of users and their work activities as well as how the system will be integrated into an organisational context and existing infrastructures. The system will need to be changed, along with the working practices, in a process of co-evolution (Rogers, 1994).

3.7.5 Summary

Whilst CSCW systems can transform organisations, there may be obstacles and resistances that arise when implementing and introducing these. Consequently there needs to be a better understanding of how systems are introduced, especially when looking at the changes required in this process of co-evolution. (Rogers, 1994).

These issues can be mitigated by understanding the organisational and social context as has been discussed in the previous sections. In addition to this, it is important to manage the introduction of the technology carefully. The next section will discuss salient concepts from the Change Management literature.

3.8 Change Management

The introduction of new technology into a context inevitably leads to change, and the management of this change is an area that has been studied extensively. Individuals, teams, and organisations all play a part in the process of change. On an individual level it may be that things previously taken for granted, initially can no longer be done as well as before. Thus it will require focus and attention to become competent again (Cameron & Green, 2012).

Lewin (1952) defines a traditional model of change involving the stages of 'unfreezing', 'change', and 'refreezing' through which an organisation prepares for change, implements this change, and then tries to regain stability.

Change can be triggered by responses to the external environment (such as advances in technology), but it can also be driven internally by management seeing a need for change. Once this trigger has occurred, it is then important to define and visualise the future (Paton & McCalman, 2008). This process can be broken down into a number of layers:

- *Trigger layer:* the identification of needs that should be formulated as opportunities rather than threats or crises.
- *Vision layer:* establishing the future development of the organisation by articulating and communicating a vision.
- *Conversion layer:* mobilising support in the organisation for the new vision as the best method for dealing with the trigger.
- *Maintenance and renewal layer:* identifying ways to ensure changes are sustained and enhanced through alterations in attitudes, values, and behaviours.
- (Paton & McCalman, 2008)

It is important to gain support for the change as often there can be strong resistance as people naturally fear the unknown and find comfort in the familiar. These fears can be for a number of reasons:

- It can result in organisational redesign
- It creates new technological changes.
- It confronts apathy.
- It challenges ideas
- It encourages debate.

(Paton & McCalman, 2008)

Change can be particularly problematic when introducing groupware technologies. Orlikowski and Hofman (1997) suggest an improvisational model for managing this in response to more traditional models, where the steps of change are defined in advance. This more traditional approach can be problematic when working in more turbulent and uncertain organisational situations often seen today. This is especially relevant to groupware whose context specific and open-ended nature make it even more difficult to predict the challenges. Thus change management needs to be seen more as an 'on-going improvisation' (Orlikowski & Hofman, 1997).

In their Improvisation Model for Managing Change, Orlikowski and Hofman (1997) differentiate their approach from traditional models by stating that changes associated with technology are an on-going process rather than an event with an end point, and that these cannot all be anticipated ahead of time. They present three types of change:

- *Anticipated:* changes that are planned ahead of time and pan out as intended.
- *Emergent:* changes that arise spontaneously through local innovation, which are not originally anticipated or intended.
- *Opportunity Based:* changes that are not anticipated ahead of time but are then purposefully introduced during the change process as a response to an unexpected opportunity, event, or breakdown.

These three types of change take place over time in an iterative fashion with no predefined sequence. However deployment of new technology often involves an initial and anticipated organisational change and over time the use of this technology will involve a series of opportunity based, emergent, and further anticipated changes. The order cannot be predicted in advance due to the way in which the changes interact with each other in response to contextual changes arising from experimentation with and use of the technology.

This model recognises that technological change takes place as an iterative series of different changes that evolve out of practical experience with new technology. However as a result of this, a set of processes and mechanisms are needed to recognise and respond to these different types of change as they occur. Thus the following two conditions are critical:

Aligning Key Change Dimensions

It is important to manage the interdependent relationship among the three dimensions of technology, the organisational context, and the change model used. For example, if a company is introducing a well-established technology with known impacts, a more traditional model (such as Lewin's) might be effective. But if open-ended, customisable technology is being introduced, then the improvisational model may provide the necessary flexibility.

Dedicating Resources for On-going Change

By recognising the on-going and unpredictable process of change, it is important to have dedicated support for this over time. This will help to ensure both the organisation and technology can adapt to the changing conditions. With groupware this may require change to the technology itself as users gain experience with its capabilities and their uses of it change over time.

This model recognises change as an on-going and potentially unpredictable process at the start. Within this model, planning for change becomes a guide, rather than a blueprint and states the importance of creating an environment that facilitates improvisation through providing a set of expectations, norms, and resources for guidance.

As the research in this thesis has dealt with the introduction of collaborative technology (or groupware) it is important to understand the potential impacts that this technology might have on the organisation and individuals within it. However due to the unpredictable and continuous nature of this, it is also important to consider on-going support for this.

3.9 Technology Adoption

When a technology is introduced, it is important that individuals and groups adopt it into their work practices. This again can be problematic when introducing Groupware and CSCW systems (as has already been discussed). Adoption is when users must decide whether to use a system and figure out how to do this (Grudin & Poltrock, 2012). This forms part of a cyclical process seen in Figure 17.

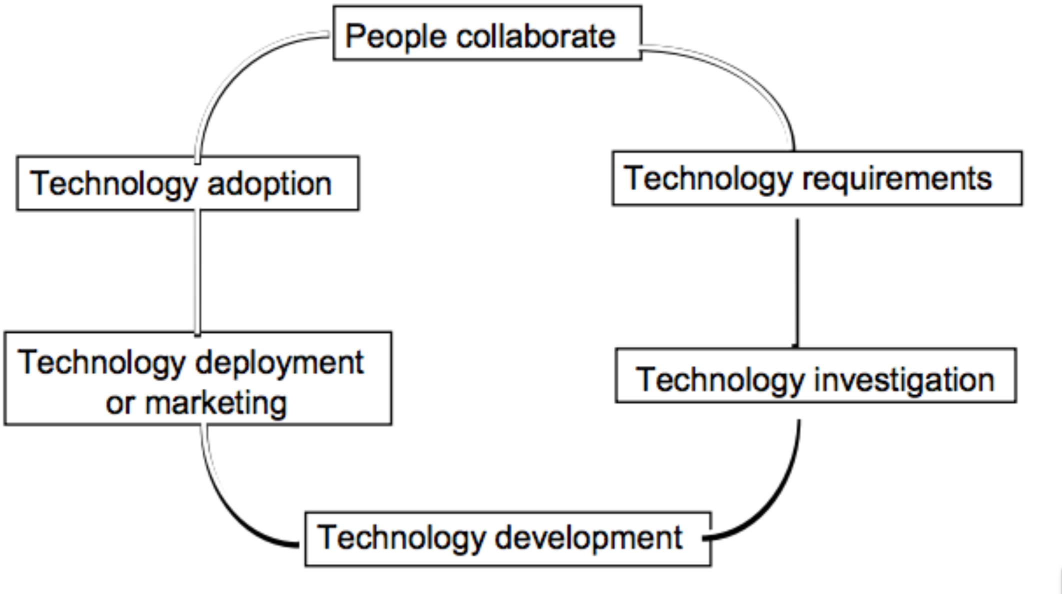

Figure 17 - A model of collaboration and technology introduction (Grudin & Poltrock, 2012)

The Technology Acceptance Model (TAM) attempts to provide an explanation of the factors that determine technology acceptance. It suggests that the perceived usefulness (the extent to which a user believes a system will help them perform their job better), and the perceived ease of use (the belief that performance benefits are worth the effort) of a system are of primary relevance to acceptance. These factors are then included in a model that attempts to predict system use (see Figure 18) (Davis, Bagozzi, & Warshaw, 1989).

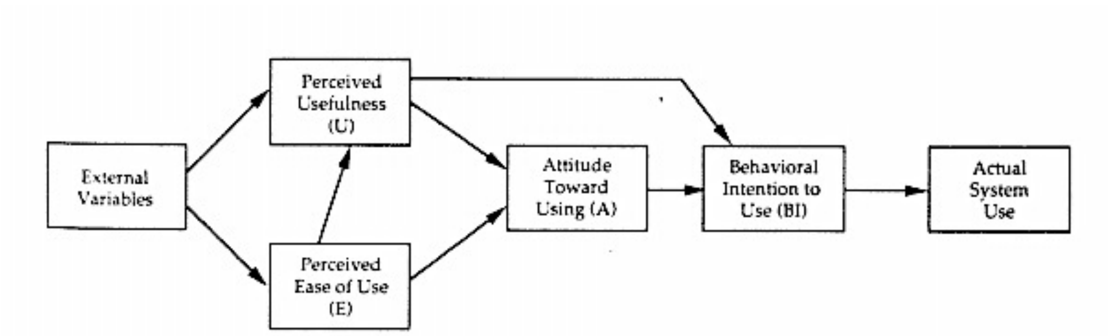

Figure 18 – TAM (Davis, Bagozzi, & Warshaw, 1989)

Davis (1989) found that perceived usefulness had stronger links to usage than perceived ease of use. This suggests that in order for users to adopt technology, they need to believe that it will help them perform their job better. This is an important consideration that should be taken into account when introducing collaborative technology into the workplace.

Technology adoption can be particularly problematic with groupware systems (as we have seen in Section 3.7.2). Kline (2001) has developed a scale (The Groupware Adoption Scale) to assess how well and why users adopt a particular groupware system. This scale was based on previously collected qualitative data based on 31 interviews with end users of groupware systems. Through this, six themes were identified as follows; Ease of Use, Training, Technical Support, Consultation, Work Needs Met, and System Capabilities. The author then created a 26 item scale that may allow organisations to evaluate why new systems may not be used, and identify possibly opportunities for intervention (by identifying which of the six subscales scores the lowest).

Summary

This section has shown how challenging it can be to get workers to adopt technology and the importance of getting them to believe that it will help them perform their job better. The six themes identified by Kline are also vital areas to consider when introducing groupware.

3.10 Tools in Use

Once technology has been introduced into the workplace, it is not the end of the design process, as the way people use technology may not be as anticipated. This is not necessarily a negative process, as it is a natural human tendency to find new uses for tools, and these new uses may be highly important.

3.10.1 Appropriation of Tools

"When humans possess a tool, they excel at finding new uses for it. The tool often exists before the problem to be solved." (Nye, 2006, p. 2).

Humans appear to have an innate ability to adapt tools to their needs. This adaptation is often seen in workplaces, where people use technologies such as email for purposes that were not intended by the designers (for example sending emails to yourself as a reminder). When users make use of technology in ways not necessarily anticipated such as this, it can be known as appropriation.

One key example of appropriation is texting on mobile phones. As was seen earlier, Norman (2010) highlighted that the use of SMS evolved from a technology driven innovation. The original purpose of SMS was for maintenance messages. However, this functionality was made available to consumers who instead used it for a number of different purposes and 'texting as we know' it has now become ubiquitous. This shows how users can take a technology and use it in a way that moves beyond the original design intention.

"Appropriation refers to the creative ways in which individual users, groups, and communities adapt and repurpose technologies to serve their own goals, sometimes doing this in a different way than what was envisioned by the designers" (Salovaara, Höök, Cheverst, Twidale, Chalmers, & Sas, 2011, p. 37). Salovaara et al. (2011) noted such emergent uses during field studies and believe that it shows a need to better address unpredictable user behaviour and the potential for novel uses of systems.

Appropriation – good or bad?

This raises the question of whether appropriation should be seen as something positive (i.e. people are more innovative than designers expect) or something negative (i.e. the designers have failed to take people and their practices into account properly)? And in addition to this, should designers abandon attempts to design with particular uses in mind and leave more freedom for users?

Dix (2007) states that appropriation is a common theme when carrying out studies of new system use but it is often seen as a sign of the users' acceptance of technology. People do not 'play to the rules' and adapt and adopt technology to their own uses in ways that designers may not have envisaged. To some extent this could be seen as improvisation, working with what there is to hand when in a situation that hasn't been foreseen. This unintended use is not a failure but shows that users are comfortable enough with the technology to use it in their own ways. Appropriation can occur when no other tool exists for the job or if other tools exist but in that specific situation it is easier or more convenient to use the 'wrong' tool.

Dix (2007) lists a number of advantages of appropriation.

- ***Situatedness*** – Designers cannot be expected to know or understand every environment and every possible task or need.
- ***Dynamics*** – On top of this, environments and tasks change. "Design for use must be design for change" (Dix , 2007, p. 28).
- ***Ownership*** – Appropriation can instil a sense of ownership. This can be a feeling of control and the ability to do things in your own way.

Subversion

However, appropriation can also be a form of subversion, i.e. deliberately using something in a way that it wasn't intended for (and to thwart its intentions). For example a sales person may falsely submit an order and then withdraw it to make sure that stock is available for a loyal or important customer (example from Dix (2007)). Whilst this can be seen as a misuse of the system, the user is trying to provide benefits to the company and thus this subversion can still be beneficial.

If logging into a system is time consuming, one user may leave the system logged in for others to use to save time. If the intention behind this is security then this may be acceptable in a secure room or where the machine is not left unattended. However, in some systems such as those that are safety critical, the system may need to be used exactly as planned (the system could have different functionality for different people) and the design should make this clear.

Design for Appropriation?

As Dix (2007, p. 28) states "The idea of planning for appropriation almost seems like an oxymoron: 'plan for the unexpected'". However, you can design to allow people the freedom to use tools for the unexpected. "They do the final design when the need arises" (Dix, 2007, p. 28).

Some tools may be difficult to appropriate. For example, an espresso machine does what it was designed for very well, but it is hard to imagine using it for any other purpose. In some situations such as this, appropriation is not necessarily needed. In the case of tools to support complex work processes such as CFD, there may be little need or indeed room for appropriation. In some situations, appropriation is not always going to be necessary. However, as has been previously stated, it can have a number of benefits. So is it possible to 'design for appropriation'? It is perhaps more of a case of designing with the knowledge that a tool may, or should, not always be used as intended.

Dix (2007) provides some principles for trying to achieve this:

'Allow interpretation' – Don't make everything in a system have a fixed meaning, but allow users to add their own meanings to some elements. For example, a free text field in a database.

'Provide visibility' – Make the functioning of the system obvious to users so that they can predict the likely effects of any actions. Therefore, not just making the relevant state of the system visible, but also the irrelevant state, so that it can be appropriated.

'Expose intentions' – Appropriation can be used to subvert systems. Rather than making efforts to prevent subversion, the developers should aim to expose the intention behind a system so that whilst subverting the rules of the system, the intent can be preserved. Exposing the intentions will avoid people making incorrect assumptions behind behaviours.

'Support not control' – Designing the system so that tasks can be done rather than designing it to do the task. If you optimise a system for one task, you may make others more difficult. In addition to this task descriptions may only be approximations, therefore 'support' for the tasks should be provided rather than complete control.

'Plugability and configuration' – create systems where the parts can be plugged together in different ways by the user. For example MacOS Automator allows users to chain together a series of actions across applications (example from Dix (2007)).

'Encourage sharing' – Let people share stories of their appropriation. A trick learned by one user may be helpful to others. More technically able users may also be able to share their findings with others.

'Learn from appropriation' – By observing the way in which tools are appropriated it may be possible to redesign technology to better support these newly discovered uses. This can be seen as a co-design process where the appropriation by users makes them partners in the design process.

Dix (2007) points out that a common theme across the principles is openness, allowing things to be used in unexpected ways, which fits well with the idea of 'designing for the unexpected'. Closed designs may appear to be more sophisticated, because 'they do more for the user', but they do not allow users the flexibility of doing things for themselves. By providing 'support' rather than 'control' you allow users space to carry out tasks in their own way.

Appropriation as a Process

Carroll, Howard, Vetere, Peck, and Murphy (2001) talk about appropriation as "the way in which technology is explored, evaluated and adopted or rejected by users." (p. 3). Figure 19 provides an overview of the process as they see it.

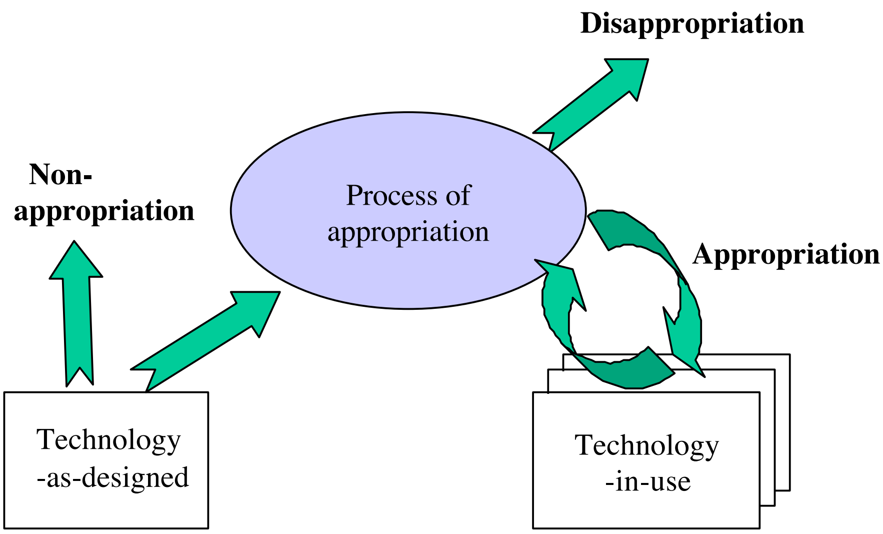

Figure 19 - Technology-as-designed and Technology-in-use (Carroll, Howard, Vetere, Peck, & Murphy, 2001)

Technology-as-designed - technological artefacts that are designed and supplied to a target audience. They contain implicit models of their intended users. The users understanding of the technology may be influenced by intermediaries such as suppliers, journalists, consultants, and trainers who are often aiming to influence whether the users or company will adopt the technology rather than considering the ways it will be used (Carroll, Howard, Vetere, Peck, & Murphy, 2001).

Technology-in-use: - describes the way a group uses technology. Different people or groups appropriate technology in different ways in different contexts, this is why the diagram shows multiple instances of technology in use. Technology-in-use is the outcome of a process, and implies that it has been evaluated adopted and embedded. This stabilisation of the technology is conditional and if conditions change, users may re-evaluate its use and disappropriate it.

The three main outcomes when users meet technology-as-designed are as follows:

- **Non-appropriation:** the users are ignorant or not interested in the technology (or its features). In this case, the process of appropriation is not initiated.
- **Appropriation:** users trial and evaluate the technology before selecting and adapting some of its features, thus taking possession of its capabilities to satisfy their needs.
- **Disappropriation** – users choose not to use the technology. This can occur at any stage during the process of appropriation. The routinisation of the technology is conditional and subject to on-going refinement.

The greater the distance between the site of technology production to the site of use, be it geographical, economic, cultural, or experiential, the greater the need for reworking. Some amount of appropriation to fit local circumstances will always be needed (Suchman, 2002).

Appropriation as a Continuous Process

"Technology is shaped and reshaped over time" (Carroll, Howard, Vetere, Peck, & Murphy, 2001, p. 5). This is often due to changes within the environment that the technology is used in. As Suchman states "…innovation and change are indigenous aspects of technologies in use, work practice, and organisational life. Even to keep things going on 'in the same way' in practice requires continuous, mundane forms of active appropriation and adaption of available resources … to the circumstances at hand" (Suchman, 2002, p. 143). Thus local improvisations are required to ensure that things continue to work.

Appropriation is therefore a continuing process, and technology should be designed with this in mind.

Summary

Appropriation of technology is a common, and often vital process. Whilst it may be difficult to 'design for the unexpected', some features such as providing flexible tools that 'support' rather than 'control' work are key. Aside from situations where a complex process dictates technology that cannot be used in other fashions, appropriation is a vital consideration. This is especially important when the working environment continues to change and thus technology needs to be flexible in its use.

3.11 Technology Design & Introduction Summary

So far this literature review has provided a summary of some of the methods and research related to the introduction and use of technology in the workplace.

Processes have evolved over time, and today it is generally acknowledged that before introducing or designing technology, the context of work should be studied. This is particularly vital when introducing systems to support collaboration as the context and social nature of the work needs to be taken into account.

There are many methods for studying context, ranging from carrying out surveys, to immersive studies of the domain and culture. Ethnography is a methodology associated with the latter, which emphasises the need to understand a culture from within. However as this is a method that has arisen from the field of anthropology its application to the field of design continues to spark debate, despite strong evidence of its success in informing design.

In addition to understanding context, it is also beneficial to involve end users or stakeholders in the design process itself. This is becoming an increasingly common practice, and methods such as MUST (Kensing, Simonsen, & Bødker, 1996) have been developed for achieving this.

Finally, when developing technology, it is important to consider how it will eventually be used and the changes that it might generate. The design process does not end as users may use the technology in unanticipated ways. This is something that should always be kept in mind when thinking of introducing technology as it is important to ensure that users can re-appropriate technology to suit their individual needs, as well as the changing environment. Tools should support, rather than control work.

These are all important processes and perspectives that should be taken into account when introducing new technology, even if the technology already exists and doesn't need to be 'designed' or 'developed'. Understanding context, and involving stakeholders in decision making are still vital, and their use in this thesis is key.

Before moving on to discuss the research undertaken it is important to briefly provide a background to research on collaboration in software development. This is to provide context for the case study that forms the later focus of the research being carried out.

3.12 Collaborative Software Development

The case study that forms the basis of this research involves studies of collaboration at Airbus, and more specifically, it eventually looks at collaboration in software development teams. It is important to look briefly at the existing literature on software development teams. However, to look into this too deeply could bias the research when looking for 'needs'. As Crabtree (2003) suggests, it is important to go in with an open mind. Thus some of the background literature below was read after the initial phases of research at Airbus.

3.12.1 Background

Software Development has been studied frequently over the last 20 years and collaboration within this process has become a strong feature of the literature.

"For all but the most trivial programs, software development today is a collaborative activity. The members of software teams must coordinate and communicate, often intensely, if their projects are to reach a satisfactory conclusion" (Schröter, Aranda, Damian, & Kwan, 2012, p. 1317).

Software development is a process that requires knowledge not just in the domain of computing, but also of the application domain (where the software will be used). In addition to this, within the domain of computing there are many different challenges such as interface design, database development, server management, and interoperability.

Software development exists on a number of scales, from huge teams of developers, creating popular off-the-shelf products, to small teams creating bespoke software for a small set of users. Thus the research on collaboration in these teams is quite broad.

Software development varies greatly across contexts, but some themes have emerged through studies that may be of relevance to this research.

3.12.2 Characteristics of Software Development

Software development, and the areas of collaboration and coordination have been studied frequently in the past. Through this research a number of characteristics have emerged some of which can cause issues. This next section will summarise some of these that may be of relevance to this work as well as the recommendations made by the authors.

Uncertainty

Uncertainty in software development is defined by Kraut and Streeter (1995) as the unpredictability of both the software and the task that the software engineers perform. This is exacerbated by changes in the functionality of software over time (in line with changes in the domain where it will be used). They also link this to the incompleteness of the specification, which occurs as a result of limited domain knowledge within the development team. They claim that "too few people working on a software project have sufficient knowledge about the domain in which they are working" (pp.70). In the process of writing a specification, the knowledge gained from customers and users is often lost.

Interdependence

This links to the integration of a large number of software components that may occur during software development. These need to work together perfectly, and all interactions between them must be anticipated. If the coordination between sub-groups creating interdependent software modules is poor, this could lead to failures when integrating them (Kraut & Streeter, 1995).

Informal vs Formal Communication

"The combination of large size, uncertainty, and interdependence requires special coordination techniques" (Kraut & Streeter, 1995, p. 70). Many previous attempts to improve software development processes have looked at techniques such as modularisation, or the introduction of formal procedures such as versioning control, but the authors (1995) feel that these have only partially addressed the problems.

Kraut and Streeter (1995) define formal communication within software development as being "communication through writing, structured meetings, and other relatively non-interactive and impersonal communication channels" (pp.71). This includes written specification documents, status review meetings, and tracking of program errors. However, these are in contrast to 'informal communication', which the authors describe as "personal, peer-oriented, and interactive communication". The issue is that whilst formal communication is useful for coordinating routine transactions, it tends to fail in the face of uncertainty, which as they have discussed, is very common within software development. This is where the need for informal communication arises. Speech is the primary means for such communication, yet "because of the tight coupling between software modules…[it] may be too imprecise to communicate well and too ephemeral to serve as a record of the information exchange" (Kraut & Streeter, 1995, p. 71).

In response to their concerns regarding informal and formal communication, Kraut and Streeter (1995) carried out a survey of intergroup coordination practices across 65 projects and 563 employees in a large software development company. When discussing their findings the authors conclude that formal methods of communication need to be supplemented with interpersonal communication in order to be successful. This is because software development requires personal communication across functional boundaries to cope with the inherent uncertainty. However they highlight problems with the ephemeral nature of information transferred in informal face-to-face conversations. This means that large projects will still require formal communication such as in requirements and design review meetings.

Herbsleb and Grinter (1999) carried out a case study of a distributed software development team, particularly focusing on work split between the UK and

Germany. Here they found that to handle the inherent unanticipated nature of the work, flexible ad-hoc communication is needed. They feel that this unplanned contact is vital. This is also supported by Gutwin, Penner, and Schneider (2004) who established in their studies of software development teams that support should be provided for both formal and ad-hoc talk on remote chat systems during development work.

Formal Procedures

Kraut and Streeter (1995) highlight the way in which senior managers are the major beneficiaries of formal project management procedures, to establish control and gain feedback. But in their survey other staff often complained that these had little impact on the day-to-day software development process. Thus frustrations may arise between the need to stick with these more formal procedures and the actual benefits that they bring to the team.

Domain Knowledge

Software has become a key means of supporting work within complex domains such as engineering, science, and medicine. Yet software developers are not usually privy to the domain knowledge needed to understand the complex processes they need to support. This can be a hindrance to their work. Chilana Ko, and Wobbrock (2009) carried out studies of developers creating bioinformatics tools, comparing the practices of those with a background in biology and those without. Their findings indicated that developers with no domain knowledge relied extensively on biologists to understand the problem and interpret the output, preferring informal exchanges with the domain specialists, to acquire 'just enough' knowledge. In related studies of usability specialists working in complex domains they found that the usability professionals saw domain experts as the best resource for understanding domain-specific nuances, yet access to these experts was limited. As a result of their studies the authors suggest the need for lightweight methods that can take into account this limited availability, whilst still allowing the details of the domain to be captured.

Further studies have found conflicting results regarding the need for domain knowledge when developing specialised systems. Sharp (1991) found evidence that domain knowledge is not needed by developers to create good designs, however Curtis, Krasner, and Iscoe (1988) concluded from their fieldwork studies that problems do occur when application domain knowledge is thinly spread across development teams.

Tools for Coordination

Begel, Nagappan, Poile, and Layman (2009) carried out web based surveys of 775 Microsoft Developers to try and understand how they coordinate with other teams sharing dependencies. Through this they were able to establish which tools were most commonly used by engineers to keep track of task dependencies with other teams. They found that overall 69% used email, 61% used a work item database, 56% talked about them in meetings, and 38% kept track of it in their head. However when it came to communication about a critical dependency they found that within teams, engineers used email (89%) or paid a personal visit (88%). When this is outside the team, email remains almost the same (89%)

but personal visits drops to 48%. Instant messaging, phone and one-off meetings were also frequently used. Many of these methods may fall under what Kraut and Streeter (1995) define as informal communication, which may have issues linked to ephemerality.

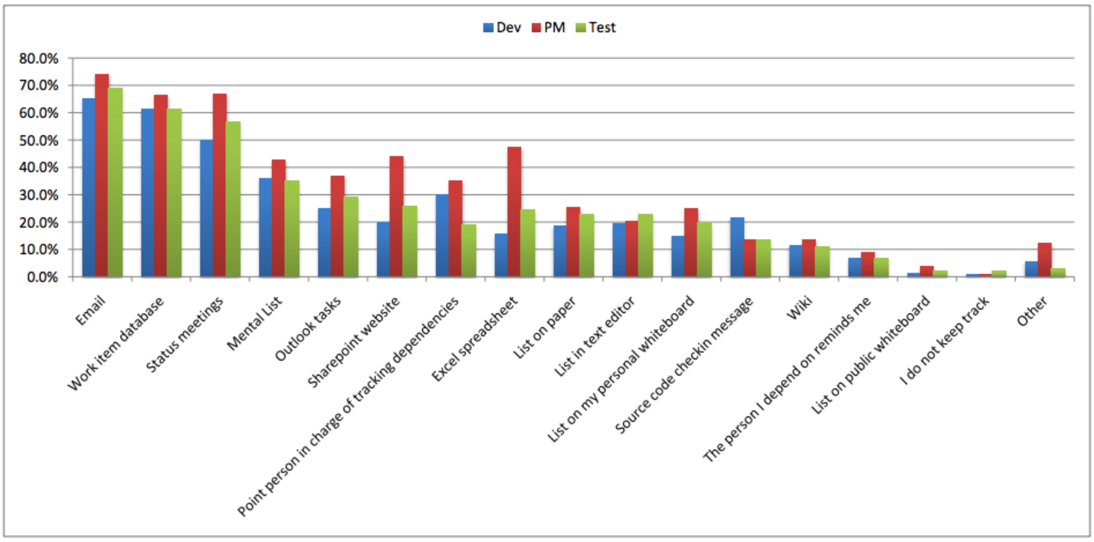

Figure 20 - Tools for Tracking Dependencies (Begel, Nagappan, Poile, & Layman, 2009)

Documentation

Herbsleb and Grinter (1999) found in their studies of distributed software development teams that in order to deal with the unpredictability of the development process, and the frequent changes in requirements and specification, that the engineers augmented documentation over time to represent and changes. Requirements are not fixed, and documentation needs to be flexible enough to cope with any changes over time.

"As requirements change, it is hard for the formal mechanisms of communication, such as specification documents to react quickly enough" (Herbsleb, Mockus, Finholt, & Grinter, 2000, p. 320).

Distribution & Distance

It is common for teams to be distributed either globally or across different offices. Herbsleb and Grinter (1999) found that issue resolution was a lot more problematic when carried out over distance. This may be due to the vital nature of unplanned, often face-to-face information communication in software development. When separated over distance, opportunities for this type of communication are less frequent. Additionally even planned communication may occur over conference calls, which Herbsleb and Grinter (1999) found to be less than satisfactory for discussing issues that have arisen. People often came out of meetings not understanding what had been agreed on.

Herbsleb, Mockus, Finholt, and Grinter (2000) found further evidence to suggest that multi-site work is associated with delays. They suggest that diminished communication across distance, as well as loss of subtle modes of face-to-face communication that co-located work affords have dramatic effects.

3.12.3 Recommendations from Literature

As a result of their studies Herbsleb and Grinter (1999) state that cross-site communications teams should "record decisions and make sure this documentation is easily available. In particular, documenting specification refinements and decisions reached in multi-site meetings will save many troublesome misunderstandings" (Herbsleb & Grinter, 1999, p. 69). They also recommend taking all possible steps to try and overcome any barriers to informal communication that may occur.

Kraut and Streeter (1995) mirror this in their conclusions by saying that the challenge should not be devising methods to minimise informal communication (as this is important for success) but in making impersonal communication "more efficient and effective by remedying the problems of expense, ephemerality, and parochialness" (pp. 80). They suggest options such as participatory design, or the hiring of domain experts to be part of the software development team (although they point out that they may lose their distinctive point of view, and thus value, if they become too integrated into the project). They also suggest methods for providing archives of meetings available as these may help capture the rationale behind decisions for people who could not attend in person.

3.12.4 Summary

Collaboration in software development has been studied in depth. This section has provided just a small selection of some of the related literature, but even within this it has been possible to identify recurring themes. These include the reliance on informal communication, the need for decisions to be recorded, and the delays associated with distributed development teams. In fact these issues are interlinked, and often boil down to the fact that informal and ad-hoc communication is needed within the unpredictable process of software development. This means that when teams are unable to communicate informally through natural means such as face-to-face communication, delays and misunderstandings are common. Misunderstandings can be mitigated to some extent through the effective recording or capturing of decisions. Yet one key issue may be that it is difficult to record these more informal communication paths.

3.13 Design Rationale Management

Towards the end of this thesis, the focus of the research moves towards tools to record design rationale. This was identified as a key requirement for tools to support collaboration in the software development team, although it was balanced by other requirements for the tool to be lightweight and flexible. This section will introduce some of the background to Design Rationale and Design Rationale Management Systems.

Design rationale is an explanation of why an artefact is designed the way it is, including background knowledge relating to this, such as deliberation, reasoning, trade-offs, and decision-making. Traditional artefact specifications generally describe they way it works, but this does not include a description of why it is designed the way it is (Regli, Hu, Atwood, & Sun, 2000).

Rationale is the justification behind decisions and it is captured and used in many ways during the software engineering process and it is a common belief that keeping track of this will aid designers. Capturing rationale involves the elicitation and formalisation of tacit knowledge. However, rationale is often captured informally and partially, such as through natural language in design documents and communication artefacts. This can make it difficult to maintain and access (Dutoit, McCall, Mistrik, & Paech, 2006).

In order to make use of the rationale in design, it needs to be captured, formalised and access needs to be provided to it (Dutoit, McCall, Mistrik, & Paech, 2006). 'Design rationale systems' can help to achieve this and can be used to record the history of the design process and provide a basis for discussions (Regli, Hu, Atwood, & Sun, 2000). Within these system it is common to access rationale through a hyper document that contains linked rationale (Dutoit, McCall, Mistrik, & Paech, 2006).

The following section briefly lists some approaches to rationale management.

IBIS (Issue- Based Information System)
Rittel developed this approach for use in planning and policy projects as a way of representing debate surrounding controversial questions, but in the 1980s Conklin adapted it for use in software engineering and created a graphical version. The initial IBIS system had the following elements:

- Issues -> questions
- Positions -> proposed alternative answers
- Arguments -> the basis on which positions are evaluated
- Resolutions -> decision of which position to accept.

(Dutoit, McCall, Mistrik, & Paech, 2006)

QOC (Questions, Options, and Criteria)
This approach has six types of elements; questions, options, criteria, assessments, arguments, and decisions. These elements are linked by relationships. It is similar to IBIS but with a focus on the discussion of questions

(e.g. where to place an interface element) (Dutoit, McCall, Mistrik, & Paech, 2006).

Features of Design Rationale Management Systems

Regli, Hu, Atwood and Sun (2000) surveyed a number of design rationale management systems in order to establish why they were not widespread in industry despite the perceived benefits that they provide. In this they discuss the common features of these system as well as the key differences:

Capture

It is important to decide which information to capture, and how to do this. This can be broken down into two stages; knowledge recording and design rationale construction. Knowledge recording is the process of capturing as much raw data as possible about the design. The rationale then needs to be extracted from this, organised, and stored (using a design rationale representation schema). The raw data can be captured through the communications of the design teams (such as email, phone conversations, and notebooks). This can be done automatically or with user-intervention.

Representation

The representation of the rationale can be descriptive, where the history of design activities, workflow, and communication between designers is recorded. This may also include which decisions were made, when, who by, and why. This approach is most appropriate in dynamic domains where there is little standardisation of the designed artefacts. However when this is not the case, it may be possible to use a more formal representation such as a node-and-link representation to structure the design arguments.

Retrieval

The retrieval process is dependent on the representation schema as well as the domain in which the knowledge is being used. There are a number of different purposes for accessing rationale and this will often differ depending on the stage of the design process.

Benefits & Challenges

The potential benefits that rationale management systems can provide are as follows:

- Greater support to project management
- Improved management of dependencies
- Greater design support
- Support for collaboration through shared awareness
- Support for downstream users of design
- Facilitation of more detailed documentation
- Help in requirements engineering.
- Promotion of PD through providing rationale access to users

(Dutoit, McCall, Mistrik, & Paech, 2006)

However, despite these benefits there can also be challenges. For example, people might not want their bosses to know the real reasons behind decisions, or they may wish to protect themselves from things later being attributed to them (Dutoit, McCall, Mistrik, & Paech, 2006).

In addition to this Regli, Hu, Atwood, and Sun (2000) list some of the key challenges that they believe may explain the lack of uptake of these systems:

- It is very difficult for systems to be reused across organisations as they need to be designed to suit the specific needs of an organisation.
- The benefit gained from using the system should encourage continued use. It needs to benefit the current user of the system, not just those in the future.
- It must be flexible enough to support both formal and informal knowledge.
- Process knowledge needs to be captured with as little overhead as possible, and avoiding interference with the natural progression of design activities.
- Facilities need to be provided for users to get required information without navigating through the whole rationale space.

It is important to consider ways to reduce the intrusiveness of Design Rationale capture, for example, ways to capture it when it is normally elicited as part of design communication (Dutoit, McCall, Mistrik, & Paech, 2006). One way of achieving this is through recording meetings and design encounters. This is the approach that this research took, as it was perceived to provide benefits without requiring too much additional effort. The next section of this chapter will look at the literature and previous research linked to recording meetings.

3.14 Recording Meetings

The idea of recording meetings is not a new concept, and technology to assist with this has been developed and evaluated on a number of occasions in the past.

FiloChat

Whittaker, Hyland & Wiley (1994) designed and evaluated a tool to allow people to index audio with handwritten notes (using a write-on WACOM tablet and a stereo microphone connected to a PC). The system allowed users to write notes on the WACOM tablet during meetings and then access the audio record by later clicking on their notes (clicking seek on audio menu and then gesturing to the specific part of the screen). They then compared the tool with pen and paper and a dictaphone in situ in nine different meetings (using observations and questionnaires) as well as conducting lab studies of fact retrieval.

Afterwards the users were also observed improving the minutes that they had generated by listening to the audio where they felt the existing notes were unclear and adding further handwritten annotations to the original notes. These could then be circulated as they were or typed up and distributed.

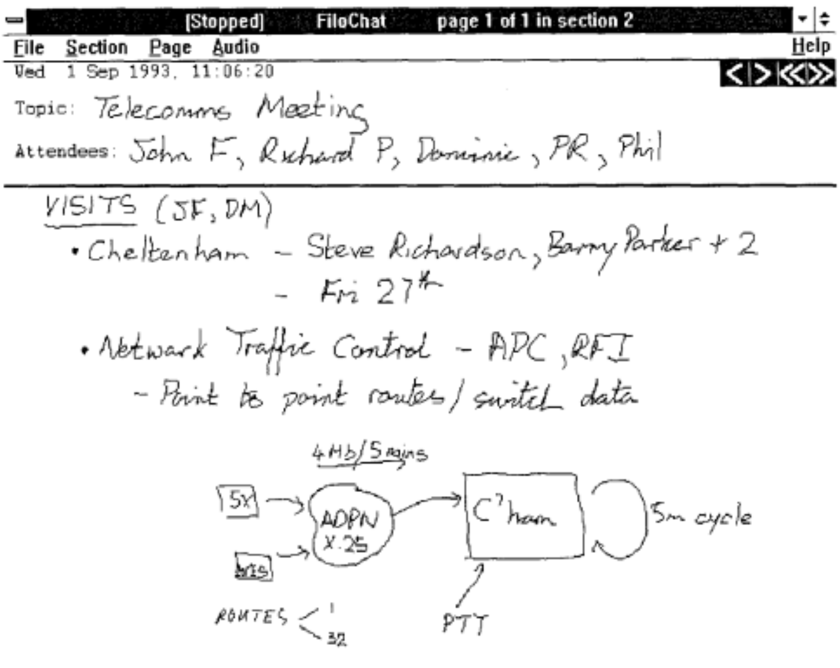

Figure 21- FiloChat Screen Shot

The main stated benefit of the system was that it allowed the generation of higher quality minutes. However they found that people took longer to write the minutes on Filochat.

Seventeen of the 29 meeting participants who completed the questionnaire felt that they did not change their behaviour as a result of being recorded. In fact one participant stated that they would have forgotten about the recording had there not been a microphone in the middle of the table. 12 people had reservations about being recorded, and some worried that it might inhibit people from speaking on occasions. People were happy with their peers accessing the recordings, but not management.

Some respondents felt that the Filochat system would be more useful in spontaneous, and haphazard meetings whilst others commented that accuracy of minutes was most important in formal meetings.

In lab tests the Filochat system outperformed both the pen and paper and Dictaphone in memory tests. It also had the most confidence associated with it. However the pen/paper condition had the shortest access time, followed by the Filochat and then the Dictaphone. Thus there is clearly some degree of trade off between accuracy and access time. In fact participants were sometimes prepared to rely on written notes or memory, rather than a speech record, for efficiency reasons.

Experienced users of the system began to mark key quotes as they were said using their own symbols showing signs of appropriation. The authors suggest building these symbols into the system in future developments to enable the identification of soundbites. However users may wish to appropriate the system in their own personal ways, and the functionality for this was already present in the system.

"The work shows that careful application design can offer users benefits without a change to their everyday work practice." (Whittaker, Hyland, & Wiley, 1994, p. 277). The use of 'handwritten notes' within the system meant that users could continue their usual note taking practice (albeit with slightly different equipment). This design idea has been revisited in more recent work, using more portable technology.

ChittyChatty

Kalnikaitė and Whittaker (2007) investigated the use of three different types of 'memory prosthesis':- Dictaphone (DP), Pen and Paper (PP) and a system called ChittyChatty (CC) in comparison to unaided Organic Memory (OM). ChittyChatty was developed on a Personal Digital Assistant (PDA) for the purposes of the study. Within the system users have a blank page which they can use a stylus to draw notes on. Whilst these notes are taken, audio is also recorded and indexed with the notes. Users can later access this audio by clicking on a specific note on the page.

With written text (vs audio) the eye can rapidly scan text to identify information. Thus with ChittyChatty, the notes can be used as a 'visual analogue' to the underlying speech, giving users a more precise way of accessing a specific part of the audio without having to listen to the whole thing again.

Figure 22- ChittyChatty Interface

In order to compare the note taking tools (DP, PP, & CC), participants were asked questions about stories that they listened to whilst taking notes. The first test occurred directly after the reading, a second test followed a week later, and a final test 30 days after that. Within these they were asked both verbatim and 'gist' questions as well as subjective response questions about the accuracy, efficiency, and usability of the tools.

The authors found greater accuracy using verbatim devices (ChittyChatty and Dictaphone) than non-verbatim organic memory and pen and paper. However organic memory was fastest for retrieval followed by Pen and Paper, ChittyChatty, and finally the Dictaphone. The dictaphone was inefficient as it didn't allow for visual scanning and ChittyChatty was less efficient than pen and paper because of the additional time needed to listen back to the audio.

Overall ChittyChatty was more accurate than pen and paper, and more efficient than a dictaphone.

In terms of the more subjective feedback, some of the user quotes during the study were as follows:
"With [CC on the 30 day session] the entire story recorded as well as having notes which means you get all the little details as well as any key facts you make notes of."
"The [DP] was 100% accurate, if you can be bothered faffing with it."
"[with DP] there is a full record…but actually retrieving info is more longwinded than other methods."
(Kalnikaitė & Whittaker, 2007, p. 77)

ChittyChatty was rated as more usable (subjective rating) than other methods. Pen and paper was rated higher than Dictaphone overall, which suggests that people may prefer efficiency to accuracy. The greater accuracy of prosthetic memory must be offset by its lower efficiency.

The authors conclude that "the extensive use of CC and the strong positive reactions to its exploitation of handwritten notes suggests that PM devices need to exploit familiar metaphors and work practices in their interface" (Kalnikaitė & Whittaker, 2007, p. 79). In addition to this, they provide further evidence for visual indexing of notes as an effective means of accessing speech records.

The Collaborative Recorded Meeting

Nathan, Topkara, Lai, Pan, Wood, Boston and Terveen (2012) conducted a controlled study to evaluate the benefits of sharing meeting annotations. During this they used a system (The Collaborative Recorded Meeting) that was a research prototype to allow users to host and join web meetings, record them, and view videos of previously recorded meetings. Meetings are filmed and during these users can create text annotations (which are time stamped). After the meeting, users can view the video along with the annotations.

During the meeting a user can see their own annotations, but afterwards all annotations can be viewed. Annotations are displayed to the side of the video, and when clicked the video will seek to the point corresponding to the time stamp of the annotation.

The authors carried out an experiment to compare the use of notes between meeting attendees (viewing the notes after a meeting), and non-attendees (viewing the notes of a meeting they did not attend). To test the system, they looked at both of these conditions with or without shared annotations. So for example, half of the participants who attended the meeting had access to their own annotations, whilst the others had access to the shared annotations. Those who did not attend the meeting had either no notes (but access to the video), or access to the same shared notes alongside the video. After attending or viewing the meeting, participants were asked factual (as opposed to 'gist') questions.

The authors found that when provided with shared annotations, non-attendees performed better than those without access to such annotations. In fact it was found that access to annotations alone seemed to be enough to perform comparably well on fact retrieval tasks, irrespective of whether a participant attended the meeting or not.

When using the system participants avoided replaying the video as far as possible. Annotations acted as indices to the video stream meaning people can find the relevant point of the video more easily, avoiding lengthy playback. The annotations became almost like tags to the data. "With short annotations, users created pointers to the important parts of the meeting with keywords" (Nathan, et al., 2012, p. 343). "It seemed users in our study were creating 'bookmarks' into the meeting that could then be used to retrieve details if required." (Nathan, et al., 2012, p. 343). The participants also strongly agreed that their annotation behaviour was influenced by the knowledge that their annotations would link to the video.

Audio Notebook

Audio Notebook is a system proposed by Stifelman, Arons and Schmandt (2001) for taking notes whilst interacting with speech recordings. It combines a paper notebook with a digital audio recorder. The user writes in the notebook but can start and stop the audio recording by pressing buttons with the pen. Later they can playback audio by pointing to the notebook with the pen (audio playback will begin from that moment). They can also use the pen with a scrollbar to navigate through the audio. The system was deployed in a longitudinal field study over five months. During this the authors found examples of users clicking on diagrams and text to recall what they meant, replaying of lectures, users adding additional notes when replaying audio, and a change in note taking habits (to more of an outline). Overall the authors suggest that the tool allowed users to pay more attention to the speakers, and allowed structured indices into the audio recordings, making the recordings more accessible and manageable.

CollabMeet

Yu and Selker (2010) have also developed a mobile meeting information capture system (CollabMeet). Moments deemed important during meetings can be recorded with one click of a button. This is a portable system and users simply click a button to capture audio from the phone. Overall the authors discovered that participants found CollabMeet to be only marginally more useful than a pen/paper and clock based system. They also suggest that the system needs to be less distracting. However they could see a positive correlation between the number of audio ‘commits’ and scores on reconstruction tests.

Automatic Speech Recognition

Kalnikaite, Ehlen, and Whittaker (2012) discuss the evaluation of two note taking tools using automatic speech recognition (ASR) along with lightweight annotation. Here users could highlight important phrases in a real-time ASR transcript, or press a button when they heard something important. These two tools (Highlighter and Hotspots) were evaluated against pen and paper with 26 users. Hotspots was found to be useful compared to the handwritten notes as it reduced overhead and allowed people to focus on conversational contributions. It also improved later recall. The highlighting tool also improved recall (without reducing conversational contributions) but users found the tool more demanding to use.

Paper Based Notes

In addition to this, whilst not directly addressing the idea of recording, (Bellotti & Smith, 2000) were able to reflect on the use of paper and notes during their studies of Information Management Systems. This is relevant to this work as it looks at how and why people take paper-based notes to record work. They saw a tension between the ideal way of working online, and an appreciation for paper. Similarly to the studies above they found that PDAs were too slow compared to paper, which may contribute to a lack of use. However paper notes remain left in notepads with only a small minority of people filing these notes. They believed that the apparent preference for paper (in this case for personal information management) was not just because it is intuitive, lightweight, cheap, and flexible, but because it is ever present and easy to get hold of when needed. It also easy to transport and stick on walls. In their words, paper is 'ever-present and handy'.

When looking at revisiting notes, they found that out of 24 interviewees 18 of them refer back to their notes (mainly linking to actions and recent notes). This is quite a high number and indicates that people do make use of notes after they have been created.

They also mention collateral which the describe as *"the many, collections of documents that our interviewees maintained and carried around with them"* (Bellotti & Smith, 2000, p. 231). People make collections of notes, email and documents for various activities, in particular for activities relate to meetings. However, organising these afterwards can be an onerous task.

In summary Bellotti and Smith (2000, p. 237) state that that "It may be a long time before the infrastructure required to support paper-based PIM is common and cheap enough to use. By that time tablet computers or PDAs will quite probably be much more efficient competing solutions than they are today and may well obviate the argument for a paper-PDA".

Summary

These studies have used a range of technology evaluations to demonstrate the benefits that 'prosthetic memory' devices can provide. By allowing people more efficient indices to audio recordings, people can more easily retrieve key information. However, when this retrieval is not efficient enough people will fall back on their own 'organic' memory that is less accurate. This highlights why audio recordings on their own are of little use as data cannot be scanned and accessed efficiently.

In addition to this, it is beneficial if these technologies are similar to and as quick as existing paper based note taking practices (which are natural, and paper is always on hand). People using FiloChat were slower at taking notes, perhaps because writing on a WACOM tablet (which has no display) is not as natural an action as writing on paper. Additionally, the Collaborative Recorded Meeting System required people to type their annotations, which again may not be as natural to people.

Despite these small issues, the systems seemed to show very promising results. However, such systems have not yet become commonplace in industry. Today the introduction of smartpens may change this, as people can take notes on paper, whilst recording audio. Writing on paper is a very natural interaction and thus will require little or no adaptation for the user. In addition to this mobile devices that can record audio along with typed or sketched notes may also provide a solution. These technologies will be discussed later in this thesis.

The next Chapters in this thesis will introduce the research carried out at Airbus.

Chapter 4

Domain Exploration

4.1 Introduction

This stage of the research began to address RQ1. *What methods and processes can be used in an industrial setting to identify areas for support in collaborative work?* It looked at a process and methods for exploring a domain in order to identify the areas for support i.e. the 'needs'.

Identifying 'needs' forms a key part of the early design work, and reflects the initial stages of the MUST Method (Kensing, Simonsen, & Bødker, 1996). Preece, Rogers, and Sharp (2002) state that 'needs' relate to users, their work and the context, thus this phase of work took time to investigate these areas.

Prior work suggests that ethnography (or ethnomethodology) is a useful technique when investigating how work is done, and identifying the 'problem space' (Anderson, 1994). It was therefore decided to take this type of immersive approach. However, it was not as simple as walking into an environment and carrying out observations. The work domain was complex, and it was not easy to know who to speak to, or what to observe.

Crabtree (2003) describes 'exploration' as a good place to start; investigating the work place with as few preconceptions as possible. To add, to this, with the complexity of the work at Airbus, it was important to acclimatise to the domain. When immersing himself in the lives of the Trobiand islanders, Malinowski needed to learn their language in order to make sense of what they were doing. Whilst Airbus UK doesn't operate in any exotic dialects, it has its own domain specific technical language that dominates a lot of the discussions and communication within the work environment. For this reason, during the first stage of this research it was vital to gain an understanding of the language and technical concepts dominating this discourse and work processes.

Therefore, in order to understand the accountable nature of the work, a sensible option was to spend time simply immersed in the workplace, understanding the terminology and getting a high level feel for 'what was going on'. This also allowed time for open-minded exploration. However the work was driven by the motivations of the early design process and the desire to eventually identify 'needs' and 'possibilities'. This stage of the research forms the initial step in the eventual process proposed in this thesis, that of 'Domain Exploration' (see Figure 23).

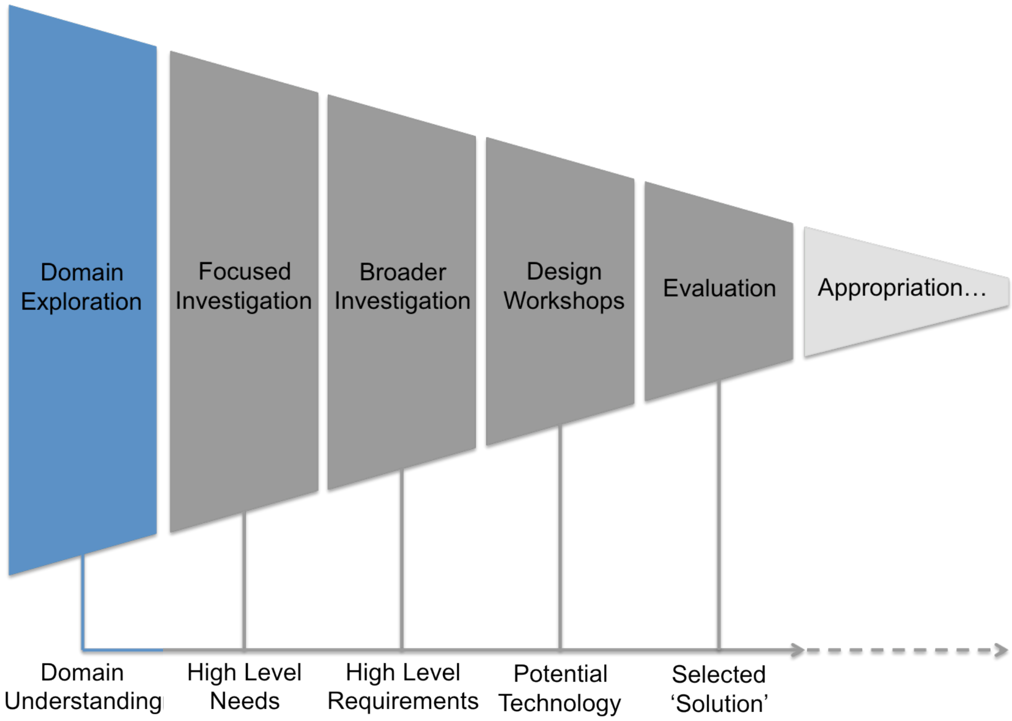

Figure 23 - Stage of Research Process – Domain Exploration

It is important to note that at this stage of the research the focus was not specifically on collaboration in software development teams, but rather on collaboration in the aerodynamic engineering domain as a whole. The research started with this broad focus, firstly to provide greater context, and secondly because it was only through this work that software development could be isolated as a point of interest.

Presentation of Findings

The following section will discuss this domain exploration, providing both reflection on the method as well as highlighting features that became key for the case study. As well as providing an overview of the themes that arose, discrete 'vignettes' will also be used to explore particular instances in more detail.

This section will also provide a further and more in depth background to the case study (as this is how the understanding was gathered).

Method

In order to fully understand the domain, immersion was important. During this (and subsequent phases) around 18 months was spent working from a desk at Airbus during the 9-5 working day (this was not continuous). During this time the preparation and background for this research was carried out, along with the data collection that forms the basis of the next three chapters. Briefly, this included informal observations and interviews, more formal data collection, and participant observations of software development activities. Essentially at this time it was possible to live the life of a standard employee, going to meetings and lunch breaks, and taking part in social activities.

However, it was also important to include some more structured sessions to gain system and job overviews that could not be achieved during these more informal pursuits. Activities undertaken by the researcher during this time included demonstrations of computer systems, attendance at departmental meetings, and observations of software development meetings. The aim of this was to introduce the domain and the department, whilst exposing the key areas of work.

Much of this work was carried out on an ad-hoc basis when opportunities arose, rather than being planned in advance.

Data Limitations
Due to the need to keep the details of new wing designs secure (as well as any bespoke systems used for this) the company have a 'no camera' policy. In addition to this audio recording is also limited and formal approval needed to be gained before any recording equipment could be used. This took time to be approved and subsequently not all interactions could be recorded. Additionally, some meetings could not be recorded at all.

Gatekeeper
In some situations it may not be clear who the gatekeeper is, but due to the research agreement in place, an internal supervisor (or mentor) was assigned. This person became the gatekeeper for this work. However, at other times, it was necessary to consult other gatekeepers from different sub-groups or companies.

4.2 Introduction to the Domain

What follows is an introduction to the domain of work as gathered during the time spent carrying out exploratory work. It is split into four sections; *the physical context*, *aerodynamic design*, the *systems infrastructure* used within the design process, and finally the *software development* that forms such a key role.

These categories have been selected because firstly, the physical context of the workplace is important grounding for an understanding of collaborative work distributed across it. Aerodynamic design forms the foundation of the work practices and thus needs to be understood. It is also forms a major source of the collaborative work being undertaken. The systems infrastructure emerged as central to the work being undertaken, as today aerodynamic design is largely dependent on computer systems. In turn, the development and maintenance of the software became a major focus of this stage of data collection due to its prominence within the working practices observed.

This section discusses the physical context, the central work processes, the computer infrastructure supporting this, and the development and maintenance of this infrastructure. These were all fundamental in gaining an understanding of a domain, the work practices, and nature of collaboration within this.

4.3 Physical Environment

As it was not possible to take photographs of the site, in order to provide context to the following descriptions the physical layout of the environment will be discussed. It is especially relevant to the context of collaborative work as teams were distributed within the office and also across locations.

Airbus is a multinational company, based across Europe. This work was based in Filton in the UK, but the company also has offices in France, Germany, and Spain. The UK site in Filton houses a number of separate buildings, and the aerodynamics group is based on the first floor of one of these, and is divided into three spaces (see Figure 24). The 'main' office is open plan and each group takes up one or two 'work areas'. Around the office there are a number of larger and more private meeting rooms. These can be booked out by anyone using the Outlook Calendar system.

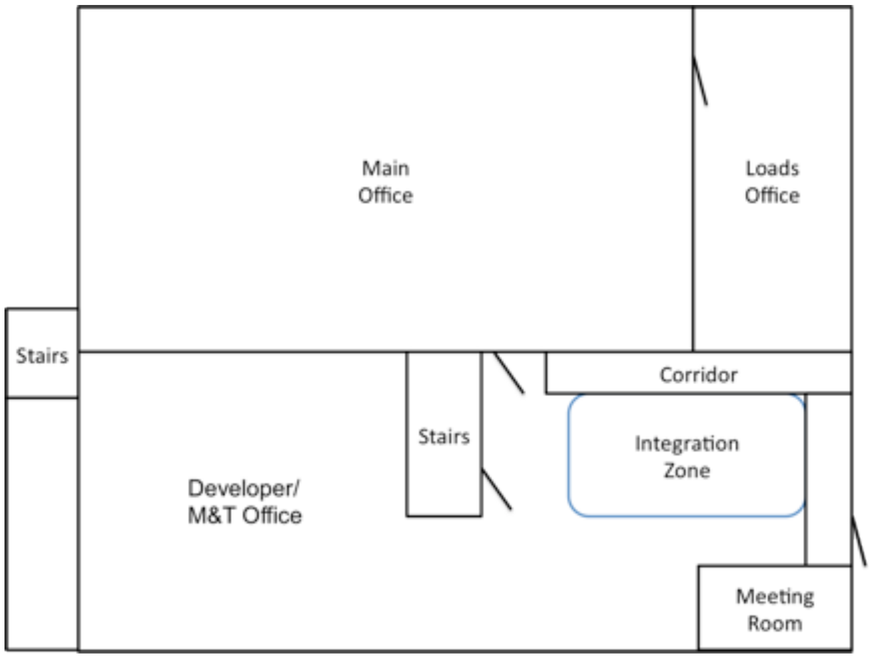

Figure 24 - Overall Office Layout

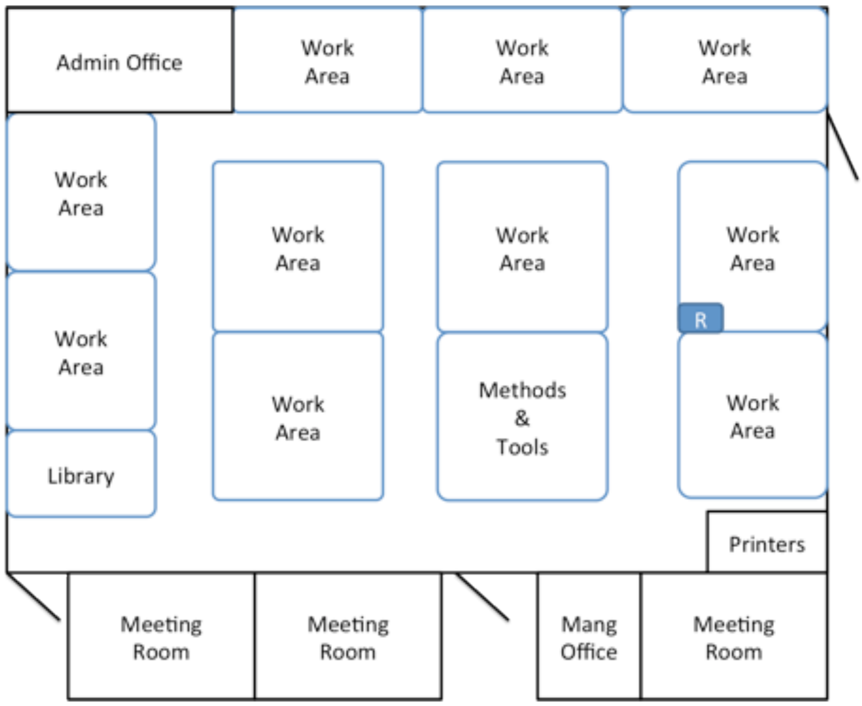

Figure 25 - Main Office Layout

The area marked 'R' in Figure 25 is where the researcher was located for the majority of the time spent in the field.

The work areas contain around 12 desks (although not all are necessarily occupied) that are separated by blue dividers. In the centre of each of these is a small table for informal meetings (see Figure 26).

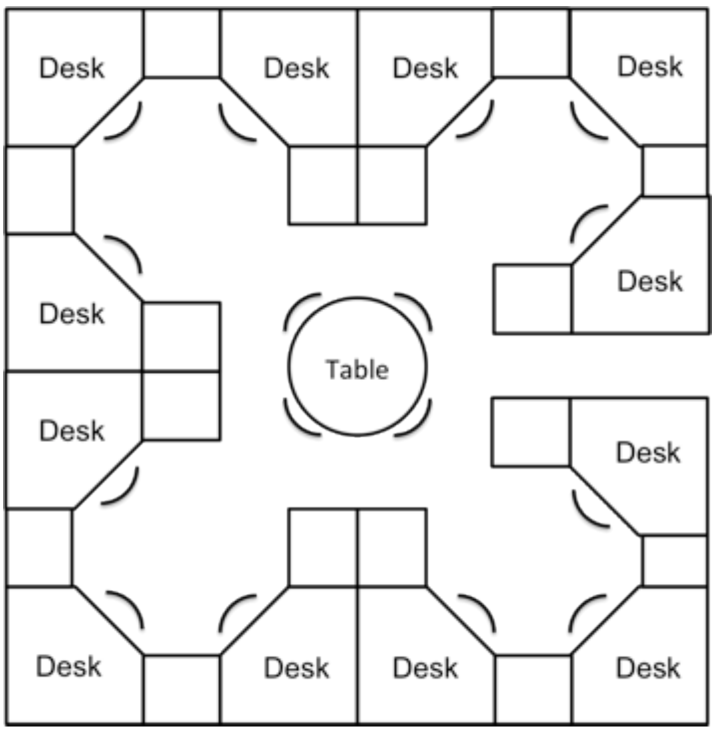

Figure 26 - Work Area Layout

In addition to the main office, some employees and meeting spaces are located in the adjoining office space. Figure 24 shows the layout of the entire floor, showing the main office and the adjacent spaces. This extra space is mainly taken up by members of the 'Methods and Tools Group' (see later explanation) as well as internal and external developers. The 'Integration Zone' is an open plan meeting space consisting of two projectors, white boards around the walls, and a number of computers. It is used for presentations, meetings, and training sessions.

Location of Software Development

Much of the software development work is carried out with an external development company (which will be referred to as SDC throughout this thesis). SDC is based in offices near to the Airbus main gates. An internal bus will take you from the Aerodynamics building to the site gates (~ 5 mins) and then the SDC offices are a very short walk from there.

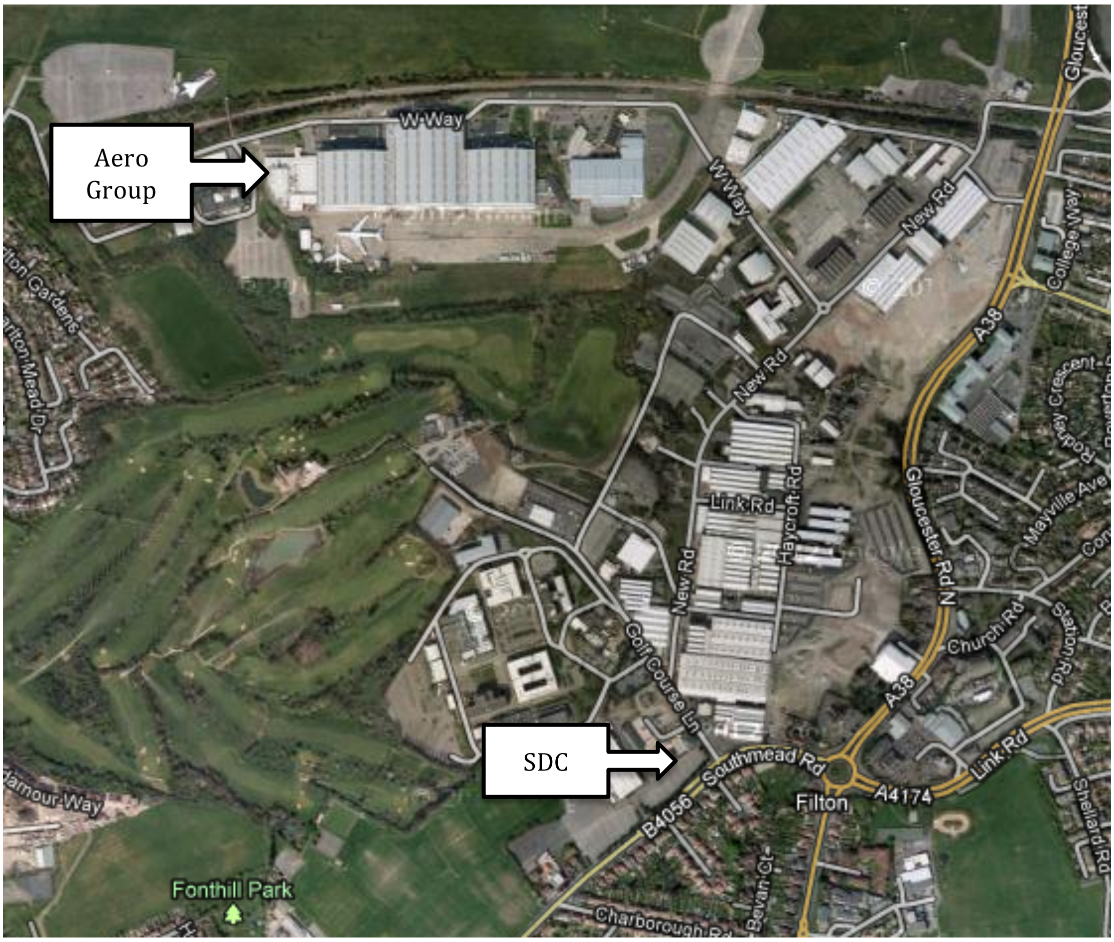

Figure 27 - Airbus Site with SDC Offices and Aerodynamics Building Marked

4.3.1 Key Characteristics

Open Plan

The open plan office allows the engineers to work together closely, and the tables in the work areas allow for informal and ad-hoc meetings to be held.

Additionally, more formal meetings can be held in private offices with the necessary computing and projection equipment. The open plan office, despite having people taking part in teleconferences at their desks, and holding meetings at the tables, did not appear to be a noisy place, and apart from isolated incidents, people were generally able to get on with their individual work undistracted.

Proximity to Software Developers
The proximity of the software company to the site appears to be advantageous. Software development (as will be shown later) is a vital activity and requires close collaboration. The ability to get on the bus and talk face to face is key, with members of the methods and tools team, as well as aerodynamic engineers, often visiting the software developers on site. In addition to this, during the early stages of this work, some of the developers were actually based on the Airbus site within the Methods and Tools areas.

4.4 Aerodynamic Design

Prior to arriving on site it was already known that the engineers in the aerodynamics group use a process known as Computational Fluid Dynamic (CFD) when designing wings. An overview of this can be seen in the Case Study Background in Section 1.2. What was less well known was the exact nature of how this work was achieved. By talking to members of the department, picking up information from simply walking through the office, or talking to people at lunch time, it was possible to build a greater understanding of this.

4.4.1 Organisation

The Aerodynamics Group is made up of a number of sub-teams, each looking at specific aspects of the design. These groups include Wing Shape, Wing Integration (dealing with the integration of control structures such as slats and flaps), Icing (looking at the impact of ice on the wing on the aerodynamics), Aerodata for Loads (providing data on the design to the Loads group), and Aerodata for Performance. In addition to this a Methods and Tools group exists which is concerned with supporting and developing the tools and processes used within the department. This is where the gatekeeper was based.

The work of aerodynamic engineers is highly specialist. Each engineer has a number of specific roles to fulfil within the sub-group functions such as working as a 'key user' in systems development, or designing a new wing structure. Examples of these roles will be provided in more depth in the next chapter.

4.4.2 CFD Based Design

Designs are produced by developing both 2D and 3D models of wings or wing sections and then running CFD on them. However, this is a complex process with a number of stages.

Something that was clear early on is that these computational models need to be in the appropriate format for computer programs to be able to analyse the airflow around the wing. This can include having to manually fill in gaps between lines to ensure a complete model. Another important process is *Meshing* where the space around the wing is modelled (as this is where the air flows). This requires breaking the space down into small sections.

Creating models, meshing, and getting files into the correct format for processing can take up a large part of the engineer's work.

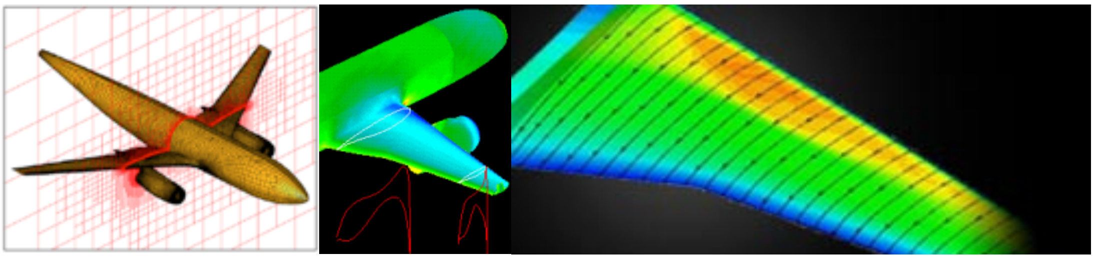

Figure 28 - Typical CFD Models and Visualisations

The 'Real' Design Process

The traditional flow of CFD design has been summarised in Section 1.2.3. However, as is often the case, the true design process varies considerably due to a number of constraints. Over time, it became clear that the actual design process could not be pinned down into a single generic model. The process differs across projects, people, and groups. However, one meeting in particular provided a good characterisation of the process. This will be discussed in the vignette below.

Vignette 1 - The Design Process (14/05/2009)

A key overview was gained when witnessing a meeting between an Airbus employee from Methods and Tools and a BAE employee who was studying the design process for other purposes. The meeting wasn't recorded but the key observations can be summarised as follows:

Systems

- A system called Wisdom is used for 2D CFD. 2D wing sections are optimised using this tool to determine the aerodynamic lift on the shape, as well as any shockwaves.
- A tool called RAVEn is used to build and design the 3D wing 'plan form'. A 'clean wing' with no gaps needs to be produced from the 2D sections using this tool. Meshing can then be carried out.

'Ideal' design process

- Using CFD to optimise the 2D wing cross sections so that the desired 'pressure distribution' is achieved.
- Producing a 3D model of the entire 'clean' wing to optimize this using 3D CFD (2D sections may need to be changed at this stage).
- Adding slats, flaps, and other structures into the wing before optimizing again using 2D and 3D CFD.
- Combining the wing with the fuselage, belly fairing (connection to fuselage), pylons, engine, and winglets and optimizing the design of the entire wing.

In addition to this, teams generate *aero data* for other groups such as loads, performance, and structures throughout the design. Once the design is finalised, this data needs to be generated again to be used in the flight systems.

In reality this isn't a linear process. These stages are all occurring at once. *Design data are shared at key stages* and all teams are working in unison e.g. wing shape, integration, loads etc. The design is always changing between these key data sharing stages but this is an accepted condition of the complex design process. There are also feedback loops i.e. when a structure can't be fitted onto the existing wing shape and so the original design needs to be changed. The design process will continuously iterate towards a better design until the final deadline is reached.

Vignette Key Observations

The design process can be seen as a 'wicked problem' (Conklin, 2005) which requires large amounts of loosely coupled collaboration ("where people need to be aware of others' activity and decisions, but without the need for immediate clarification or negotiation" (Olson & Teasley, 1996)) and data sharing between sub-groups, and outside the aerodynamic group. Whilst the engineers are working on the 'same' design, they have had to fragment it into manageable sections that are then combined at key points rather than communicating daily about changes.

Reflections on Method

Being part of a meeting where the design process was being explicitly discussed with another person was a very useful way of gaining an overview. The need to simplify it for a single meeting meant that a concise description was produced. Picking up snippets of this over time had led to a somewhat confused picture, and this meeting made the understanding much more concrete.

4.4.3 Key Characteristics

Multi-Disciplinary Design

The design process is highly multi-disciplinary, involving groups outside of aerodynamics. The design process of the wing involves consideration of a number of factors, such as air flow (dealt with by aerodynamics), the loads (forces) on the wing, the physical and material construction, and the integration of mechanical devices, fuel tanks and engines. For this reason, the aerodynamics group need to collaborate with and produce data for a number of external groups based not only in Filton, but also across Europe. This means that much of the work requires engineers to both communicate with, and send data to, other groups.

'Design' Interfaces

When reading about CFD, aerodynamic design, and computer aided design in general, you may imagine engineers spending most of their time viewing 3D models (as this is often the images that are promoted). Prior to studying the design process 'in the wild' it was assumed that the engineers would spend much of their time looking at what is typically imagined when thinking about CFD (see

Figure 28). However, in order to compare and analyse designs in more detail, much of the engineers' is spent looking at graphs that show the pressure distribution along the wing (amongst other things). These can often become focal points in discussions and meetings. For this reason, a number of graph-based interfaces exist, including viewing a wing shape as a graph (see Figure 29 and Figure 30).

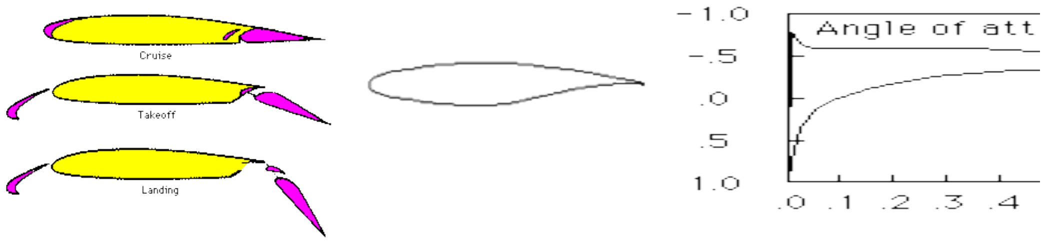

Figure 29 - Wing Sections and Graph

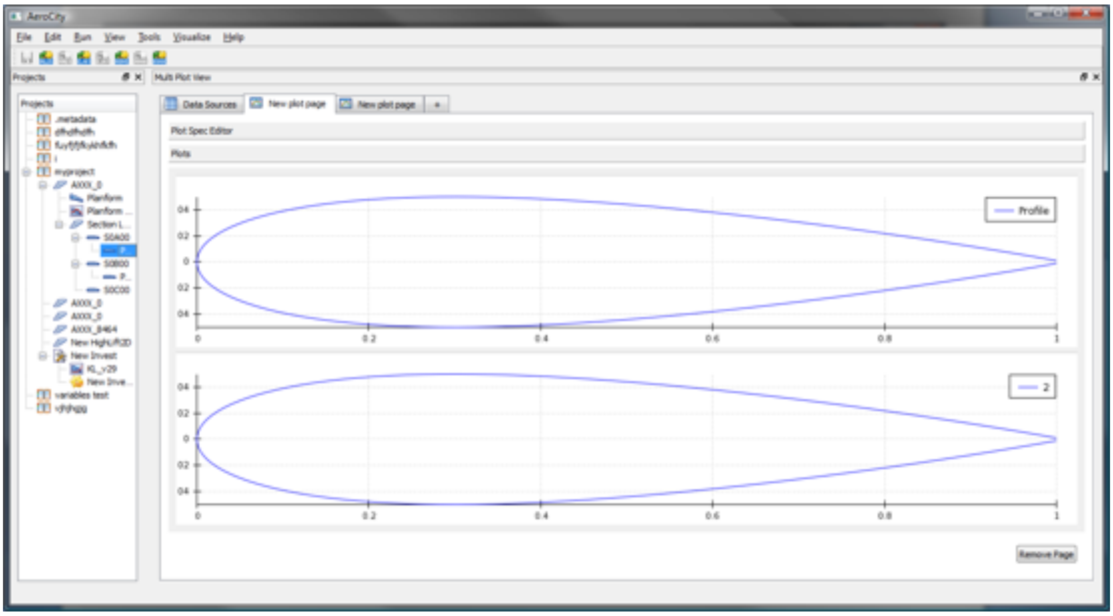

Figure 30 - Typical Interface for 2D Design

Collaboration

Due to the need for groups to share data and designs, the work is inherently collaborative. However, if you were to walk through the office you may not be aware of this due to the seemingly solitary nature of the work at times. Much of an engineer's day is spent using software to set up, run, and analyse CFD jobs. However, there are a number of weekly meetings (either face-to-face or over WebEx) where teams provide updates on the work that they have been doing, and any results from this. The design process in aerodynamic design runs over years and for this reason the collaboration, whilst central, is not necessarily on a daily basis and can appear invisible to an outsider.

Data

Much of the engineers' work involves taking a design, running CFD (or similar) on it and outputting the results of this. This leads to a large amount of data being produced. It was possible to witness the regular group emails asking for people to clear out 'unnecessary' data from shared repositories. This legacy of data also means that searching for the right file or output can be a time consuming process (and the development of a search engine for this will be discussed in a later vignette). The management of these data (some of which are shared) forms a large part of the engineers' role.

4.4.4 Summary

It is unsurprising that the 'ideal' process is very different to the actual work carried out. In this context, the complexity and variability of the design process, and the tightly coupled nature of the work make it almost impossible to represent the process accurately. However, for the purposes of designing support systems, mapping the exact process isn't necessary (as the tool will be supporting the articulation work behind this). Instead it is important to focus on the accountable nature of the work and building a picture of the key characteristics, in this case focusing on the collaboration involved.

The systems used by the groups are also of interest, as the complexity lies not in the interface, but in the way in which the processes of work are represented. With the large amounts of data generated during design, searching for and dealing with data forms a large part of the engineers work.

4.5 Systems Infrastructure

As can be imagined, when dealing with a complex and specialised computational design process, the systems infrastructure is complex, and constantly evolving as design techniques are improved. This infrastructure is formed of the systems being used by the engineers in their work, and the interdependencies between them. There are a number of systems used throughout the design process including legacy and cutting edge technologies. A 'design' and the associated data need to flow through these, despite the need for a variety of different data formats.

It is important to consider this infrastructure, as the majority of the work of engineers is largely dependent on these systems, either using them in the process of aerodynamic design, or helping to design or update them with the software developers (working as 'key users').

There are a number of systems in use by the Aerodynamics group. These include CFD based systems, CAD systems and data management tools. In addition to this tools exist for the more mundane aspects of the work such as productivity, communication and coordination tools.

The communication and coordination tools are predominantly off-the-shelf tools such as Microsoft Outlook (the use of the calendar and email is ubiquitous). Some standard design tools used such as the CAD package CATIA (see Figure 31) are also off the shelf technologies that can be integrated into the engineers work, however others are developed or customised in house (or with an external team of software contractors) as they are highly specialised. In fact, the CFD software being generated is often cutting edge and provides a competitive edge to the design process, and thus needs to be generated in-house.

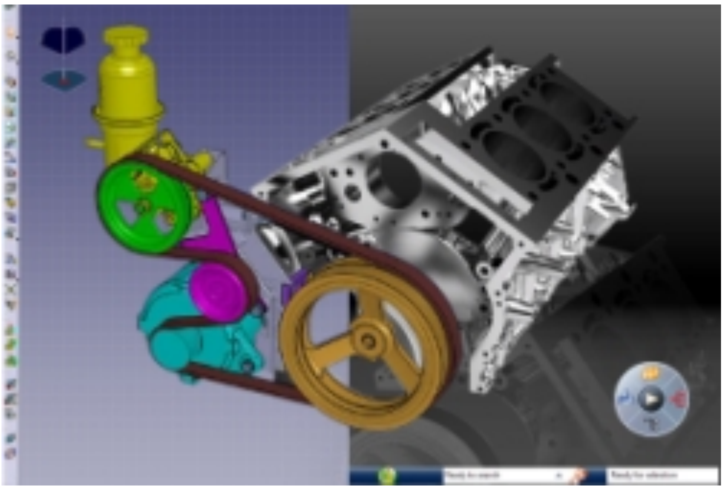

Figure 31 - CATIA (taken from http://www.3ds.com/)

Much of the work of the aerodynamic engineers is involved with transferring design data between systems. For example, a 2D wing geometry will need to be imported into a tool for 3D design. Once the designs are created they may also need to be converted into a format suitable for the CFD processing. Again, once this has been achieved, the results may need to be transferred into a more visual format for sharing and discussing with others.

As has already been described, the engineers are highly dependent on computer systems to get their work done and any changes in technology will impact the way in which they work. In turn, when looking at the infrastructure from the point of view of other stakeholders such as the Methods and Tools team, or the software developers, any new or updated system must fit into this infrastructure without too much extra work being created. Data types need to be as compatible as possible, ensuring that interfaces between them work smoothly.

The complexities of the systems used within the design process became clear during a Process Mapping initiative that was being run. This will be discussed in the next vignette.

Vignette 2 - Process Mapping

During this early exploratory stage of research, the company was taking part in a LEAN Engineering initiative (a process to slim down the work practices, making them more efficient). Within Aerodynamics a specialist facilitator helped a group of engineers map a specific process within their workflow.

The process was mapped during two meetings with key stakeholders involved in the process. The main facilitator of the meeting (trained in LEAN engineering) provided post-it notes and a table length piece of paper for mapping the process. The meeting attendees then wrote the design stages on post-it notes and arranged these in chronological order across the paper. In doing this it was already noticeable that the processes could be different depending on who was carrying it out. In addition to this some ‘rework’ loops existed.

Once an agreement was reached on the process (not an easy task as many people had their own ways of doing it) the estimated duration of each task was listed, including the minimum and maximum completion times. In addition to this, potential points of failure were listed for each stage of the process. The systems used to support each task were also listed.

It transpired that for this single process, over 21 different computational tools were used and 1/3rd of the total task duration was spent translating data between tools (i.e. exporting it into the correct format). This highlights the complexity of infrastructure that any engineer or systems developer needs to work with or be aware of. i.e. developers need to try and reduce the amount of data formatting and conversion.

For privacy reasons, these maps cannot be included in this thesis. However, Figure 32 includes the outline of the process map, with all other details removed aside from the name of the systems used in each step. This map was created by the researcher from the post-it notes and annotations made in the meeting and was later used by the aerodynamics team when restructuring their work.

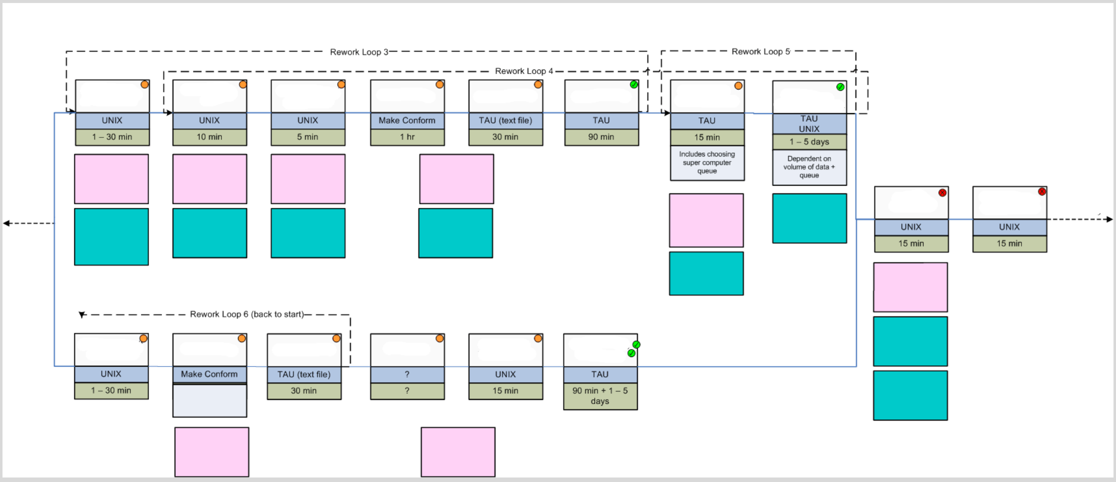

Figure 32 - Example Process Map (pink boxes -> possible problems, turquoise -> potential solutions)

Summary

As a means of gathering information this process mapping exercise was useful as it allowed the complexities of the working process and systems infrastructure to become visible. For example, it was possible to tally up the number of systems used by the engineers in a single process. Many of the tasks listed were only necessary to make systems compatible, for example, changing the format of a file generated from one system in order to be able to use it in another. This highlighted the complex systems infrastructure that had evolved over time. It also showed the often routine nature of the design tasks for the engineers.

Introduction of Technology
Introducing technology into the workplace is complex due to the need to ensure that it fits into the existing systems infrastructure that has evolved considerably over time. This means ensuring that it is compatible with any data inputs, some of which may be from legacy systems, as well as creating compatible outputs. In addition to this, issues such as security and privacy of data need to be considered. The systems may contain data or discussions of data relating to wing design ideas and even the exact wing geometries. This data is very valuable to Airbus and they understandably do not want competitors to access it. The techniques being used, such as new CFD processes, are also very valuable to the company.

System Example
Early on in the time spent on site it was possible to gain system overviews. These were carried out both by users and the developers themselves. One example of a system that quite effectively highlights the nature of the work is Wisdom.

Wisdom
Wisdom is a graphical software application to support the aerodynamic design of wing shapes. It was demonstrated by R (an engineer in the Wing Shape group) who as an eventual user had been helping with the development. The system allows engineers to edit wing shape data in terms of a planform (a 3D view of the wing) and 2D cross sections. It allows the engineers to create the wing shape and then run basic CFD on it that can be viewed in graph form next to the wing. In addition to this it can be used to reverse this process, starting first with the desired airflow, and generating the shape that would create this. The interface is quite simple with navigation of documents on the left, and the graph and wing shape views on the right.

Other systems that were demonstrated include systems for managing data files, systems for setting up CFD jobs, and tools for data analysis. These ranged from new systems (such as Wisdom) to systems that had been used for well over a decade that the engineers trusted as being robust and reliable. Many of the systems could be operated through the command line, and the engineers seemed very comfortable with this.

4.5.1 Summary of Systems Infrastructure
Having been exposed to the systems infrastructure and its complex role in the design process, it became clear that any future intervention would need to become a part of this. Therefore some salient features of this should be noted.

Legacy Systems
The infrastructure has evolved over time, along with the design process itself. Some of the systems are incredibly robust, and have been used for decades. This software forms a vital role in development. Users have trust in these systems and are incredibly familiar with them and there is little need to replace reliable systems that can still do their job (*'if it aint broke…'*). However, newer tools to support advanced CFD development are being created and need to be able to work in conjunction with the existing infrastructure. This may explain some of

the additional steps in aerodynamic design caused by the necessity to convert file formats.

Complexities of Using Systems

In their day-to-day work engineers have to deal with a number of different systems that often require various steps to be carried out to achieve a goal. Due to this, the engineers are very used to performing what might be considered to be 'routine' tasks such as converting data into the correct format. They may even have their own workarounds to deal with this. As a result the engineers are fairly resilient and don't necessarily question why these added tasks need to be completed. This means that when new systems are added, the users are less likely to demand a system with a simple look and feel, or a reduced number of steps. They are used to this, and it is seen as part of their job.

4.6 Software Development

Software development is vital to the aerodynamic design process. The process is dependent on computing technology and much of this is developed in partnership with an external software development company (SDC).

During the domain exploration stage the opportunity arose to attend and participate (as an interface designer) in some software development meetings. Through these meetings, it was possible to build a good picture of the development process and the stakeholders involved. At this stage of the research this was not the main focus, especially as it was a more familiar domain to the researcher. However, it was necessary to build a picture of the structure of the teams as well as their processes.

Software development is a major activity at Airbus, due to the demand to support the most cutting edge computational design processes. As technology improves, more and more of the process can be automated. Therefore the role of the engineer is increasingly concerned with aiding in the development of the new system. This essentially involves helping to feed their domain knowledge into a system that will support or automate aspects of this in the future.

It is also a complex process due to the need to support the engineering processes, as well as fit into the existing, constantly evolving systems infrastructure. The following sections will briefly summarise the structure of the teams.

Development Teams

The systems are generally very specific and often the user base can be small (up to 10 final users). The development teams are made up of the following roles (although the exact details and titles vary across projects):

Software Developers

The software developers are mostly based at SDC (or the European equivalent companies), or occasionally in-house. Their role is to provide the software know-how.

Key Users
These are usually aerodynamic engineers, and they are selected to represent a (usually small) group of users. They attend meetings, and advise on their processes and the domain knowledge required for this. Most projects will have one or two key users.

Business Process Leads (BPL)
The BPL is often from Methods and Tools. This is a multi-faceted role, advising on the domain, existing business processes, and systems infrastructure.

Collaboration
During the software development process there are many face-to-face meetings involving some or all of these stakeholders as well as email exchanges, and sharing of documentation (both formal and informal). Teleconferences are also a common occurrence due to the distributed nature of the teams.

Due to the highly complex nature of the system, large amounts of time are spent getting the system to fulfil its basic role. This process involves constant discussions between the developers and holders of domain knowledge (the key users and BPL).

Knowledge
An early interest in this research came in identifying the background of the software developers, and it became clear that this was not always computing. Instead some had come from Physics and Aerodynamic Engineering itself. This was an early indicator of the importance of understanding engineering concepts when developing the software used at Airbus. The systems need to support complex engineering processes and thus require an understanding of these. The users can communicate as much of this as possible, but the developers will need to comprehend it in order to implement it.

Summary
The main realisation during this phase of the research was the prominence of software development within the company. As has already been stated, the aerodynamic design process relies heavily on software tools. As the design process evolves, the software needs to change to keep up with this. As technology advances, the role of the user is becoming increasingly focused on helping create tools to support their work. In addition to this, a number of other stakeholders must work with them to develop this software.

In contrast to the aerodynamic design process the software development process is much less formal and structured, and takes place over comparatively shorter time frames (although still taking a number of years at times).

4.7 Domain Exploration - Summary

During the domain exploration stage it was possible to begin to see areas that would merit further investigation. This included areas where it was not possible through high-level exploration to pick up the finer details of work, or areas that were deemed to potentially have 'needs' for greater support.

The two original areas of focus were collaboration in aerodynamic design and collaboration in software development teams. Through studying these, it was possible to identify key characteristics such as the complexity, and non-linearity of both of the design processes. The company is always seeking to improve its CFD and aerodynamic design technologies and new tools and techniques are being constantly developed and integrated. This results in a complex, changing environment, where the development of tools and software is a vital and prominent collaborative process.

Within aerodynamic design the main focus for further investigation became identifying and studying the key points of collaboration. This should also look at the use of tools in the design process, and the way in which engineers manage their work across these.

The area of collaboration in software development became a greater focus than was anticipated during the first phase of research. Subsequently future investigation needs to look at this in greater detail. Areas of interest include the transfer of domain knowledge from the aerodynamic engineers to the development teams. In addition to this, the aspect of design associated with introducing systems into the already complex infrastructure should be investigated.

4.7.1 Reflections on the Methods

Through carrying out this phase of research it has been possible to reflect on the success of the techniques used.

Studying Collaboration

The work at Airbus, both in the aerodynamic and software design processes, is highly interdependent (although structured in a loosely coupled fashion). They are both dependent on multi-disciplinary collaboration. However, during this informal, exploratory stage of ethnography it was difficult to identify the key points of collaboration, as well as the mechanisms for this. Aerodynamic design projects have design meetings yet these take place within closed meeting rooms that for privacy and security reasons cannot be attended without prior permission. Additionally whilst emails and phone calls may be used, as a casual observer it is difficult to identify when this is happening.

Data Collection

Data collection techniques in this domain can be problematic. For example videoing/photography was not allowed. Audio recording was permitted, but written approval needed to be gained, and audio recordings of certain meetings could not be taken off site. This is all for understandable data security reasons, but posed a challenge when wishing to record events for later analysis and documentation. Instead it was necessary to keep detailed notes of events and thoughts.

Gatekeepers

Having an accessible and enthusiastic gatekeeper was key to gaining access to the right people within the domain. However, it is important that gatekeepers do not begin to guide the research too heavily. Reasons for this are that as Hammersley and Atkinson (2007) suggest, they may have an interest in presenting the domain in a favourable light. This is understandable, but when looking for 'needs', it is important that the researcher is able to identify 'areas for improvement'. This can be seen as the researcher looking for 'problems', something that a gatekeeper may feel is not presenting the company in an optimal light. Therefore it is important to make this clear to the gatekeeper and other members of the organisation early on and ensure that they understand this perspective.

Domain Knowledge

Whilst the description provided here avoids the excessive use of domain specific terms, in reality the work of the engineers and the software developers was densely populated with it. Many meetings were broken up with explanations of key concepts such as 'wing camber', 'control structures', and 'belly fairings'. Yet this was not as easy in larger meetings such as departmental 'Drumbeats'. Over time it was possible to begin to understand the language (but not necessarily speak it), which in part was helped by regular visits to Wikipedia and aerodynamic design textbooks. This was vital in being able to understand discussions during meetings, even those with software developers.

General Thoughts

As a method, the ethnography at this stage provided a number of benefits. Getting to know the domain, its processes, and languages allowed for more efficient interactions and the ability to attend meetings without the need for participants to constantly explain terms (which can detract from the main aim of the meeting). It also enabled an initial 'feel' for the key functions of the department to be gathered. These were often different to what was anticipated, such as the important role of software development, the complexities of the computing infrastructure, and the 'invisible' nature of collaboration in aerodynamic design.

Chapter 5

Focused Investigation

5.1 The Collaborative Nature of Work

Having built an understanding of the domain, the roles, and systems used, it was possible to begin to study the nature and collaborative characteristics of the work in more detail. It had become clear that collaboration within the aerodynamic design teams was complex and large scale, and to an extent, invisible to an external observer. The employees appeared to work alone much of the time (sitting at their desks for much of the day), yet their work formed part of a vital collaborative design process that whilst loosely coupled, was highly interdependent. Due to the lack of visibility, it was decided that this process should be investigated more closely. In addition to this, due to the obvious importance of software development, collaboration in this area was studied more closely.

This stage of research formed the 'Focused Investigation' stage of the process proposed in this thesis (see Figure 33).

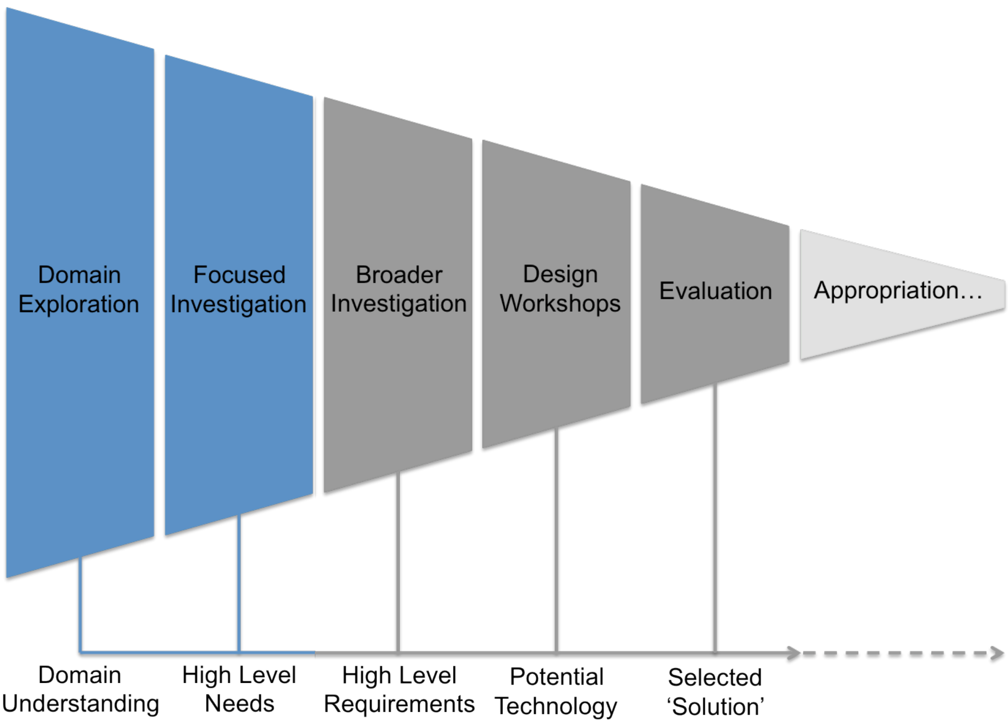

Figure 33 - Stage of Research Process – Focused Investigation

5.1.1 Case Studies

The following section will be split into two distinct sections:- Collaboration within Aerodynamic Design, and Collaboration within Software Development.

The section on collaboration in aerodynamic design will focus on one particular project team, from the perspective of three different roles. The decision to focus on this particular project was to develop a more focused understanding of how a project fits together and the interdependencies between the engineers working on it. The particular project chosen was an opportunistic selection as it was an early phase design project that was currently active. Other projects were coming to an end or were more focused on the maintenance/development of existing designs.

The section on collaboration in software development will focus again on one particular project (although also informed by interactions outside of this which occurred during the course of the time at Airbus). This project was again an opportunistic selection, as it was a current project that was not likely to come to an end in the near future (which would not have been ideal). It was also a project that was representative of and similar in structure to a number of other development projects.

5.1.2 Methods

During this stage of the ethnographic work time was spent looking in more detail at the collaborative nature of the work being undertaken by both the aerodynamic engineers and the software development teams.

The methods used for these two areas were quite different, as the software development domain could be studied as a participant observer, and were more flexible, and accessible. However, the process of collaboration in aerodynamic design required a more structured approach.

5.2 Collaboration in Aerodynamic Design

It was not possible to take part in aerodynamic design meetings as a participant observer due to insufficient knowledge of the domain. For this reason a variety of more focused data collection was undertaken.

At this stage in the design process, it was becoming desirable to communicate the findings with others (such as fellow academics), as well as bringing the salient aspects of the context into focus in order to identify opportunities. For this reason, a theoretical framework was considered as an option to help bring this into focus more clearly.

5.2.1 Theoretical Frameworks

In the previous discussion of ethnography, the debates surrounding the applicability of theory have been covered. With the debate still continuing, it is important to keep an open mind when approaching this research and therefore a framework was considered.

There are many theories and frameworks that have been used in the past by HCI practitioners carrying out fieldwork and ethnographic studies. These include distributed cognition (Hutchins, 1995), Situated Action (Suchman, 1987), and Activity Theory (AT). Nardi (1996) compared these three frameworks when studying context concluding that AT was the richest and most comprehensive, especially as it engages with difficult issues such as consciousness, intentionality and history.

As has been discussed in the Methodology Chapter, AT can be useful in studying the social nature of work, and for this reason it was selected for use in this stage of research. It was hoped that it could further bring into focus the collaborative and tool dependent nature of the work.

5.2.2 Method

A mixed-method approach to data collection was chosen for this stage of research, and concepts from AT guided the choice of techniques and questions.

Participants

Three participants were involved in the study, all engineers within the aerodynamics department, but working in separate skills groups (Wing Integration, Aero Data for Loads, and Aero Data for Performance). The three engineers were involved in the same project (A30X), an early stage design for a new plane. Each took part in the study for one week (a different week for each). The start times were staggered in order to avoid biases. For example, if all studies began on Monday there may be issues with the data on this day being less rich due to the effects of them getting used to being studied (or the opposite if their enthusiasm tailed off towards the end of the week).

The participants were selected through the *gatekeeper*, who approached each member individually. Approval was gained from each of the participants' skill group leader.

The participants were as follows:

- A from Aerodata for Loads, who was also working as a key user on the development of a new tool.
- J from High Lift Devices who was working on the design of new high lift device.
- S from Aerodata for performance, who was also working as a key user on another tool.

Diary Study

Due to the seemingly hidden nature of the collaboration, a diary study was selected, as it would allow a log of work to be provided. This would hopefully uncover the times at which the engineer was collaborating and in what manner (be it through work being sent to another, or through a face-to-face meeting).

The diary was designed to capture data relating to concepts from AT in order to understand all aspects of the engineers *activities.* This included the *community* (who helped you and who relied upon the work?), the *artefacts* used (tools and systems), and the *goals* of the tasks.

The 'questions' were as follows, and were represented as columns in a spread sheet:

- What tasks have you been working on?
- What was the goal of this work?
- A brief description of this work
- Systems you used to achieve this (inc. Word etc.)
- Other tools you used (i.e. paper, notebook etc.)
- Who else (if anyone) helped you to complete this work?
- Does anyone else rely on this work being completed?
- Were there any issues when carrying out this work?

The engineers were instructed to fill this in either once a day or throughout the day. The diary was provided in both electronic and printed formats, to provide flexibility.

It should be acknowledged that there are limitations to diary studies, such as them being a distraction for participants who are otherwise busy, and the fact that it can be difficult to verify how much the entries match what actually happened (Carter & Mankoff, 2005). However, as the diary study was being used in conjunction with observations and interviews it was hoped that the latter issue would be somewhat mitigated. With the former, the participants were allowed to fill in the diary when it suited them, with daily face-to-face or email based prompts as reminders.

Observations

In order to gain more detail on the activities and to get a feel for the actions involved, observations were also carried out. The scheduling of these was based on suggestions from the engineers, when asked to choose a representative selection of tasks. In addition to this, ad-hoc observations occurred to deal with impromptu activities. Two A30X project design meetings were observed which all participants were scheduled to attend.

All observations were recorded with a dictaphone (as has been mentioned, video recording was not permitted due to privacy issues). Notes were taken to capture any key visual events such as actions on the computer interface. In total, the observation time was 3.5 hours.

Interviews

Interviews were held with each engineer at the beginning of the week. These were used to gather background information on their role, goals, and activities. These were around 20 - 30 minutes long and provided context for the observations and diary studies.

Combined Methods

The rationale behind the combined use of these methods was that whilst observations may yield the richest data, the presence of an observer might bias the work being carried out (for example, someone else may not approach the person being studied as they may assume they are busy working with the observer). A diary study would also allow for the context of this work to be captured and cover periods between observations, as it would not be feasible to observe multiple people during all working hours. Interviews were used to help understand the wider context of the engineer's work and gain some insight into their opinions on collaboration and system use.

5.2.3 Analysis

The data analysis was largely qualitative and provided an opportunity to try out different approaches. The interviews and some of the observations were transcribed and bottom up coding applied. In addition to this the content of the diary studies was coded.

AT was not used explicitly during the analysis, but it guided the coding process and attempts were made to 'fit' the findings into the activity system framework.

5.2.4 Findings

In total, this data collection provided 3.5 hours of observations, along with two, two-hour formal meeting observations. In addition to this, 29 diary entries were created. This section will firstly look at the observation and diary studies. The project meetings will be discussed in a separate section.

Whilst AT mainly guided the data collection, it was also used informally in the analysis to 'explain' some of the observations and diary entries. Some of these will be presented within this section.

Observations

J Observations

J was working on a new high lift device during the week of studies. Two individual sessions were observed, along with the group project meetings that will be discussed later.

During the 1st observation it was possible to observe J setting up a model in CATIA (a CAD package). During this time they repeatedly used their physical notebook to refer to old design parameters. They manipulated the CAD design either directly or via input boxes for typing in parameters. This process continued during the entire observation, with the work being quite technical and fiddly.

AT Analysis
Goal: Create a model of the device for CFD analysis.
Object: The CAD model of the device.
Tools: CATIA, notebook, domain knowledge.

Activities: Setting up the CAD model and calculating design parameters.
Actions: Inputting parameters.
Operations: Reading from notebook, typing into input boxes.

During the 2nd observation J was exporting the completed design into another format and transferring it to the correct location for CFD processing. Again J used their notebook repeatedly to refer to information, and they also used a calculator at times (to check calculations). The process involved saving the design file in another format to reduce file size, FTPing it to a workstation in Germany, and logging into the workstation (using German commands). The work on the workstation involved creating a folder for the file and then running the CFD. As the CFD processing takes time J said that they would run it in batches, doing some more later that day. Once the batches had been processed J would view the results in another system. Then they would go back to the original model in CATIA and change the shape as necessary. J mentioned saving all past parameters from previous design into a history file in Excel to record how the design had changed.

AT Analysis
Goal: Send model for processing.
Object: The CAD model of the device.
Tools: Notebook, calculator, FTP program, German workstation, data storage structure, System for viewing results, Excel, Knowledge of German.
Rules: File structuring procedure.

Was there a contradiction occurring between the way in which the German workstation (an instrument) had been designed for the community in Germany, without considering the potential of other users not sharing the same 'language' (rules)?

A Observations

In total three observations were carried out with A. Two were planned and another was ad-hoc as an unplanned meeting occurred. During the first observation A was working on comparing two different plots of data. They were using a custom built tool made with Matlab by a fellow colleague. They were mostly setting up the plots, adding legends and annotations to them. This was to provide context for later sharing. Like J, A also made significant use of their notebook, jotting down file names and Mach numbers. Again the work also involved creating folders in a shared drive for saving the work.

In the second observation A was again working with Matlab plots. This time A was carrying out a mixture of coding and interacting with the plots directly. A was seen using their notebook for calculations, noting down values from the screen. One interesting point during the meeting was when A went to ask for help from the person who had created the Matlab tool (they sat opposite). A then found problems with logic in their code. They hadn't properly cleared the values in an array. Other tasks observed included the process of converting data into the 'official transnational format'. Overall A described their work as dealing with lots of large data sets and working with less well defined tools than in other groups.

> ***AT Analysis***
> A, as the subject is having to change the format into an 'official transnational format' to comply with 'rules' designed to facilitate the sharing of 'objects' across the 'community'.

In the final observation, A was called to a meeting with someone from a different group to help clarify an issue. This took place on a table in the office space, where both of them had notebooks open, along with some drawings and numbers. The meeting was concerned with clarifying which calculations had been used by an external company. A was able to identify that something looked 'off' with the data but the pictures that had been sent were not clear enough. After carrying out some paper-based calculations of ratios, A made some suggestions and the meeting ended. After the meeting A said that this type of scenario was quite common, as misunderstandings often occurred. A then returned to the work they were doing before and the observation continued. During this session A was still working on the comparison of data plots. They were unable to identify where errors were coming from so needed to ask a colleague for a second opinion. Unfortunately it was difficult for A to get the context across and the colleague was confused. This is where the observation ended.

> ***AT Analysis***
> Whilst the colleague that A consulted was within the same community on one level (they are in the same team), they were not within the same project community (as a result of the division of labour) and thus they did not have the shared knowledge (instruments) regarding the design context.

S Observations

Only one observation with S was possible. This was the observation of a teleconference where S was presenting work on a process that they had been trying out. Due to the inability to record over the phone (the audio was playing through a headset) it was difficult to analyse this afterwards. However, the general feel from the meeting was that S was explaining a new process for carrying out a task along with attempts to validate it. This involved sharing slides with data, plots and calculations. However there were issues as not enough context was provided on the slides regarding the calculations. As this was a new approach there was quite a lot of 'problem solving' talk.

> ***AT Analysis***
> Again there appear to be issues with colleagues not having enough contextual information, but in this case it was not so clear how this linked to concepts within AT. The community share the same domain knowledge, and they work on the same object.

Diary Entries

Below are two example diary entries. These are fairly typical entries and they show the way in which the collaborative nature of the work was captured.

Tasks: A30X data
Goal: Verify work done by supplier.
Description: Go to location on unix. Look at plot data to visually/sanity check initial results.
Systems: Unix, Email (gave file location), Excel (for plotting)
Other tools: Notebook to record action.
Anyone else helped?: [colleague name]
Rely on: Supplier to continue work. Ultimately Loads.
Issues: Data were incomplete. Investigation into problem is needed.

Figure 34 - Diary Study Example 1

Tasks: Wing flap. Set up CATIA model (details removed for security)
Goal: To provide aeroshapes
Description: In CATIA, inserting (device) and editing design parameters.
Systems: Data previously in Excel but copied onto paper for ease of use.
Other Tools: Paper -> parameters copied from excel. Notebook -> some measurements noted.
Anyone else helped: Some CATIA advice from [team member].
Rely on: Will feed into systems.

Figure 35 - Diary Study Example 2

The following section will provide a summary of the key findings from the diaries, observations, and interviews.

Collaboration

Thirteen of the diary entries mentioned receiving help from someone else. Another four activities were meetings and thus involved the project team. The most common types of collaboration reported in the diary studies were *sharing information* (33%), *sharing expertise/advice* (25%) and *gaining input data* (16%). These were categories created during coding. Sharing information included activities such as presenting findings to team members. Sharing expertise or advice concerned instances such as A getting help from their colleague. Gaining input data was one of the less direct forms of collaboration, where the engineers were using data or information generated by others in their work.

In the interview J talked about having lengthy negotiations with a member of the Wing Shape team who worked on the design that they were now working on. They talked about ways in which J could help assist the High-Lift team in their goals. They also talked about working with the ‘Kinematics’ group based in Germany who deal with the movement of the wing devices. This can include discussions on how far they can get the new device to rotate. Both of these are examples of dealing with the design interdependencies. In order to do their job J needed to negotiate the possibilities of other aspects of the design, such as the shape and movement.

When asked about their Goals J also highlighted that it was about meeting the goals or targets of someone else further up the design chain. This might be a particular target for the results of the CFD analysis on their current designs. J also mentioned discussions with a member of their team with more knowledge than them who they go to for advice.

There seem to be at least two communities that engineers interact within; one of these is the community who share the same design goal (i.e. achieving CFD analysis targets)). The other is those who share the same domain or procedural knowledge (i.e. R consulting a team member for process support).

Face-to-face Collaboration

During the observations (which only made up a small percentage of the week) there were three instances of face-to-face collaboration. All of these took the form of problem solving. Fifteen percent of the diary study entries reported face-to-face collaboration.

J mentioned that on their project they would generally 'go out there' (Germany) most months for a big update meeting. In the mean time communication was over the phone, and emails. NetMeeting was used for discussing pictures.

Remote Collaboration

Fifty percent of the diary study entries reported the use of collaborative technologies to support remote work. This included simple technologies such as email, along with tools such as NetMeeting to support remote meetings.

Ad-hoc Collaboration

Much of the collaborative work was ad-hoc. During A's observations, much of their directly collaborative work was ad-hoc. On two occasions they asked for advice from a fellow team member, and in the final example, a colleague came to ask them for advice.

Tools & Systems

Twenty of the diary entries mentioned the use of paper and/or a notebook as 'other tools'. The engineers always used a notebook for recording their work in, as well as making calculations. It was very rare to see an engineer apart from these. They are used for traceability purposes and must be kept.

The systems used varied between each engineer, with them using tools specific to their roles. J used CATIA considerably, whilst A used Matlab, and S used an Excel based tool that contained equations. In addition to this, email was listed 10 times. Excel, Word, and Powerpoint were also frequently listed. This highlights how common more generic systems are, as well as the more specific tools.

When reflecting on the tools used J mentioned non-tangible things such as the knowledge of how to use things and what makes a good design ("I guess you just know"). With systems being complicated and lacking user guides, much of the system use relies on memory.

Computational tools mediate the way in which the engineers interact with the design object. Due to the specialist nature of each of the engineer's roles, these are very specific. Each activity requires a different system. Yet in order to share the data with the community (who will use different tools) they need to be converted into the correct universal format. This means that an engineer spends much of their time converting or preparing data for sharing.

5.2.5 Project Meetings

This section will look in depth at the observations of the design meetings. This is being presented separately as the analysis methods were different and the granularity of this was much finer.

Analysis of Design Meetings

When it came to analysing the formal design meetings, it was decided that it might be beneficial to try using codes that had already been used in studies of design meetings. This was aimed at trying to identify the higher-level more general components of the discussions rather than the domain specific features (i.e. to avoid "not seeing the wood for the trees") The decision was made to use coding developed by Olson, Olson, Carter, and Storrøsten (1992) in their analysis of collaboration in small group design meetings. These were as follows:

Table 2 - Coding themes from (Olson, Olson, Carter, & Storrøsten, 1992)

Issue	The major questions, problems, or aspects of the designed object itself that need to be addressed.
Alternative	Solutions or proposals about aspects of the designed object.
Criterion	The reasons, arguments, or opinions that evaluate an alternative solution or proposal.
Project Management	Statements having to do with the activity not directly related to the content of the design, in which people are assigned to perform certain activities etc.
Meeting Management	Statements having to do with orchestrating the meeting time's activity.
Summary	Reviews of the state of the design or implementation to date, restating issues, alternatives, and criteria.
Clarification	Questions and answers that someone either asked or seemed to misunderstand.
Digression	Members joking, discussion of side topics, or interruptions having to do with things outside the content of the meeting.
Goal	Statement of the purpose of the group's meeting and some of the constraints to work under.
Walkthrough	A gathering of the design so far or the sequence of steps the user will engage in when using the design so far.
Other	Time not categorisable in any of the previous categories.

Although these were devised for software development, they are quite generic and it was felt that they could easily be applied to other domains. During the coding it was very easy to apply these to the meeting discussions.

Meeting Overview

These meetings took place in one of the meeting rooms around the outside of the office and were scheduled on a weekly basis. They were attended by the engineers from each group working on the project, as well as 'an expert'. The

Experts are senior engineers who advise on projects. Project members from other locations (Spain and Germany) also joined via teleconference.

The meetings were conducted by the MCI (Major Component Integrator) who sits in the aerodynamics group, but has the role of ensuring that the design work is integrated with other activities. They attend meetings with other MCIs and are responsible for sharing information about these other project activities. The MCI would normally log into the computer in the meeting room to open various documents such as meeting invitations, email, and project documentation.

Key Observations

Whilst the content of these meetings cannot be discussed in detail for data privacy reasons, some observations from each of these will be summarised below.

Overall Process

Each meeting would begin with a cascade of information from the 'Plateau'. The plateau is the group of team members (including the MCI) from the wider scope of the project (i.e. other groups as well as Aerodynamics) who work together to share information between projects, and arrange key activities. The MCI, who is part of the plateau, presents any key information to the team during the meetings. Once this is complete, there is generally a mix of 'round table' updates, where each team member provides an overview of what they have done and are planning to do, as well as any specific presentations on topics of interest or key project activities. In the meetings observed there was a presentation on some data analysis as well as a presentation from 'the expert' on a design concept.

The cascading of information and the sharing of individual activities and future plans, took up quite a large portion of the meetings. Some quotes are included below.

MCI: So we'll start with some plateau news, then we have two major items, well I've got a list of technical surgeries for the second half of the year, which I'll just get you up to date with. There's some news on [removed] work, status [removed] and then we'll get into the analysis that some of you have been doing. And then something on [removed] which I have been working on, and then the round table if that's ok with everyone?

MCI: Right there's nothing else left from the plateau. Round table. A do you want to go first?
A: [provides update on work done and issues, mentioning the confusion which was discussed in the meeting observation]
....
MCI: So you're looking to extract this data?
A: Yes and just making sure it's consistent before it goes in. It's not a high priority but just needs to be done soonish, cos we're thinking about putting it forward for ....runs. Short term future.
MCI: When is soonish?
A: End of next month?
MCI: End of next MONTH....that's ages

A: If we can get it done in July then I think we'll be fine.

N (wing design engineer): If I can get a couple of weeks (sighs) without too many meetings and things…with unfettered work I can get it done.
I: Is it more realistic to assume another week to be safe?
N: Quite possibly.
MCI: Another week being…
N: Well, yes, into July. That's what I've told [colleague].
N: Apart from that I'll be on holiday from the 12th or something.
MCI: I don't know if [colleague] has requirements for it sooner than that but I don't see [colleague] or I needing it before the first … runs are coming back.

Collaboration with Remote Team Members

During the first of the design meetings, it was interesting to note that initially the assumption was that no colleagues from other sites would be attending via telecon. However, fairly early on, an email appeared on the MCI's Outlook screen from a colleague wanting to join. Time was then spent waiting for them to dial in via NetMeeting (to view the computer screen remotely). Later another colleague did the same. However eventually one of these colleagues asked to leave once they had provided their update as they couldn't hear anything. The communication with these colleagues did not appear to be as easy as with the co-located team members. It also required additional activities such as setting up NetMeeting.

Use of Artefacts

During the meetings a number of additional artefacts and tools were used. Firstly the teleconferencing occurred through Polycom devices on the table, as well as the use of NetMeeting for sharing the computer screen.

Outlook itself became a key component of the meetings, with the MCI opening the meeting invitation that contained the agenda. Emails from remote colleagues were also opened during the meeting (see above) and attachments with relevant design data were also accessed.

As well as Outlook, the MCI opened an Excel plan of the project tasks that showed the progress with these (planned, completed, or deployed) and this became a focus for some planning discussions.

Concurrent and Related Activities

One of the major points of the meetings, as has already been seen, was to share information from the wider context of the project. It seems that due to the number of concurrent and related activities, the team members are often keen to get involved with these more directly. The quote below shows how several colleagues wished to attend a meeting mentioned by the MCI. However in this instance it did not seem practical.

MCI: It's hoping to start more of a regular discussion with [colleagues names] so we get a better understanding of what's going on in [group name].
I (the expert): I completely agree, we've got to work closely with them. If I can, I might like to try and listen in on that one.

...
E: Can I be involved as well?
N: I was going to say can I be involved as well? Can we come and maybe find a room with a screen?
MCI: I was expecting it to be a sort of informal sit down…
I: Well if it is it might be impractical but let's ask…. particularly if they were going to be showing each other some data or information that would be useful.
MCI: I don't think that's the case for the moment. I think it's more of a sort of a first meeting, saying what are the issues, what are the interactions.
I: Right, maybe it might be more appropriate for them to just give us the output of that meeting, what came out of it.

Meetings Summary

Through attending these meetings it was clear that much of the work was project management, the cascading and sharing of information related to the project, and discussion of future schedules (such as who would be on holiday). Thus there was little direct talk about the design. The coding confirmed this, where it was found that in the first meeting Project Management was coded 111 times, with clarification (53) and meeting management (29) behind this. In the second meeting 'Meeting Management' was the most prominent (50), followed by 'Project Management' (33). However, this would seem to be the aim of these meetings, as much of the 'real' design work takes place in front of computers.

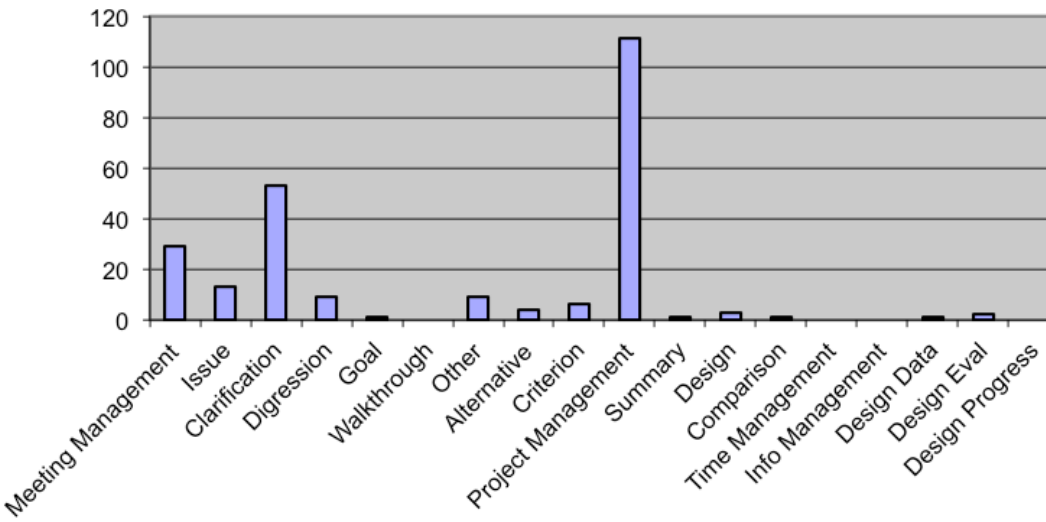

Figure 36 - Meeting 1 Coding

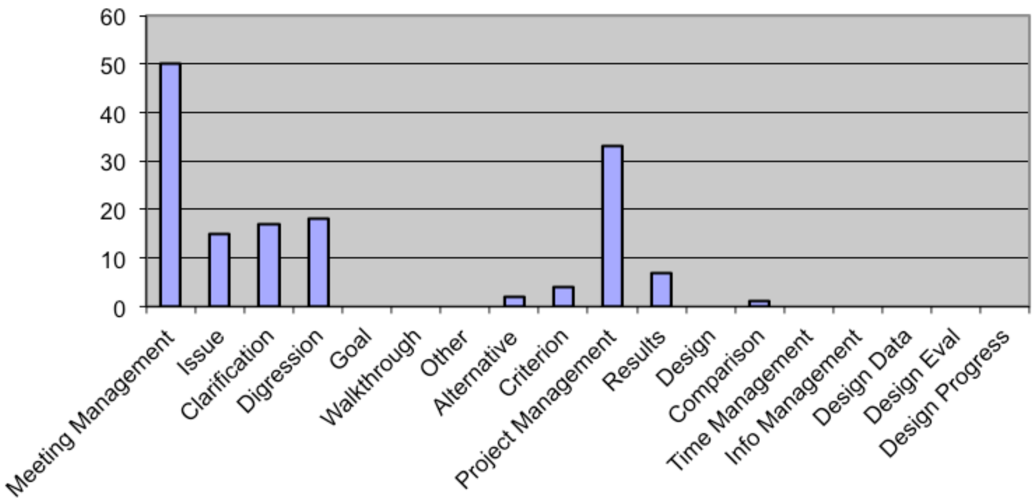

Figure 37 - Meeting 2 Coding

5.2.6 Discussion of Findings

This section brings together the analysis of the individual observations, diary studies, and meeting observations.

Types of Collaborative Work

Through this work and subsequent analysis the characteristics of the collaborative aspects of the work became clearer. The different types of collaboration seen in the observations and diary studies could be categorised as follows:

Techniques & Processes: Sharing results, knowledge, and expertise relating to techniques and processes used with design.
Design Data: Sharing results from design work and analysis.
Problem Solving: Working together to solve problems through sharing expertise and ideas.

Design Data

On one level the engineers are working on a design, and through this they generate data that are passed onto other teams or individuals in a raw or processed format. This may simply be a file with results in, or a presentation of these in a meeting. This form of collaboration is often happening through electronic means such as FTP or email, or behind closed doors in meetings.

Techniques and Processes

Secondly, the engineers are constantly working to revise and improve the processes used in design and for this reason much of their work revolves around trying out and validating new procedures. This may involve collaboration to get the process working, or the sharing of the results for discussion.

Problem Solving

Due to the complexities of the domain and the work that the engineers are doing, often problems arise. This may be in getting a new process to work, or through not understanding a particular design result. For this reason another aspect of collaboration is in the need to gain advice from those who may be able to help solve this problem, due to their particular expertise. Due to the nature of problem solving, this is mostly ad-hoc collaboration.

These types of collaboration may have not been clear through earlier work as much of this takes place very briefly or behind closed doors. The majority of the time an engineer will be working alone at their desk doing design work or trying out new techniques and processes, but instances of collaboration are still vital, despite being minimal.

Project Coordination

Within the formal meetings, the discussions were generally linked to sharing findings from individual work, cascading information from other project activities, and discussing future schedules. This is where the collaborative work on a larger scale is facilitated, i.e. ensuring that the aerodynamic engineers align their work with other activities, and making sure that they have the right information to do this. The majority of this work was seen as 'Project Management' but could also be seen as 'coordination' work.

5.2.7 Reflections on Methods

The technique as a whole proved useful in gaining an overview of the work carried out on a weekly basis. By focusing on particular activities it was possible to get a more fine-grained understanding of the collaborative processes. However, there were a number of different data collection and analysis methods that were used during this phase of the research and these will all be reflected on individually.

Observations

The data gathered during the 'non-meeting' observations (those where the engineer was at their desk) was not particularly rich for identifying collaborative practices. These sessions mainly involved them working on individual tasks. However the presence of an observer may have biased this, as the engineers appeared 'busy' so people may not have approached them. Additionally the engineers seemed uncomfortable with being watched and this seemed to disrupt their flow at times.

These observations also tended to become too fine grained in the level of detail being elicited relating to the work being carried out. For example, spending time watching an engineer create a CAD model was very interesting, but did not yield the type of contextual information regarding collaboration that was desired. The tasks generally lasted longer than the duration of the observations (sometimes taking up to a day or more) and the instances of gathering data and sharing it with others were limited to brief periods at the beginning and end.

However, observing the design meetings and other ad-hoc discussions was a great way to see the nature of collaboration. It also felt more natural and the engineers seemed more at ease. By being available at all times, it was possible to be called into ad-hoc meetings as and when they occurred. This was an unanticipated but vital part of the research.

Diary Studies

The diary studies became a useful tool for building a context around the work practices of the engineers, and also for identifying the collaboration within this. By asking specific questions about who helped with the work, and who relied on it, it was possible to draw out instances of 'collaborative' work that perhaps the participants wouldn't have noted themselves, for example gaining assistance, or sending files to others. It was also possible to gain a better understanding of the collaborative tools they used.

Comparatively, the diary study drew out the bigger picture of the engineer's work better than the observations. The observations of desk working did provide useful insights into the 'real' work of the engineers but they could be limited in time. Instead it was more useful observing meetings.

Identifying Collaboration

The observations and diary studies had strengths and weaknesses in their utility for identifying the collaborative nature of the work. The diary studies drew out the wider context of the way in which the work of the engineers fitted together and relied on other people, whilst the observations identified the often 'isolated' nature of the engineers' work.

If this data collection stage were to be repeated in the future it would be beneficial to combine diary studies with time spent working in the same environment as the engineers. Through this the context of the work could be captured, as well as a high level feel for their work (by observing them in a more informal manner). Meetings should also be observed to see examples of the face-to-face collaboration. Additionally, to put this into context the observations could be carried out over an extended length of time, within a project based 'case study'. By decreasing the level of granularity and focusing more on the higher-level context of the work, it may be possible to build a clearer picture of the collaborative processes.

The Role of AT

AT was most useful in guiding the data collection process, than during analysis. Whilst it was used to try and structure the findings it was felt that little additional insight was gained through this. For example, it was possible to see the way in which the engineers worked in a variety of communities, each with different goals, but the interest in this lies in the more nuanced ways in which they interact with these communities.

The data collected may have been richer as a result of considering concepts from it. For example, by identifying goals as a key driver of work, it was possible to see that whilst collaboration was not always direct, most activities formed part of a larger shared goal. In addition to this, it allowed focus to be placed on the tools used, which actually highlighted just how many of these there are.

Overall it was felt that much of the richness in the data wasn't being clearly represented by the AT framework. Whilst it provided a means of communicating the findings to others (something which may have value in other contexts) it did not generate the clarity that had been desired. In reducing the data into a theoretical framework, the richness and depth of the context that are so vital to design appeared to be lost. In addition to this, learning about the theory was time consuming and whilst there may have been some benefit it was not enough to outweigh the burden of this (reflecting the concerns mentioned by Nardi (1996)). However, it must also be noted that a more experienced researcher, with a stronger background in this area may have used the framework more effectively and no formal analysis methods were utilised.

Coding

Using coding during analysis provided a means of quantifying activities and meeting content that was useful for reflection. It also allowed for themes to be identified. However it was not as useful in highlighting areas of collaboration.

Using the existing codes (used by Olson, Olson, Carter and Storrøsten (1992)) when analysing the design meetings was an easy process and enabled higher-level patterns to be established (such as the focus on meeting management). However, this top down process may inhibit some interesting concepts from being identified. Coding is something that becomes easier with experience and this process in the context of this research was a useful learning exercise. In the future, bottom up coding should be carried out before being grouped into themes to produce more general 'codes' or concepts.

5.3 Collaboration in Software Development

As well as studying the collaboration in aerodynamic design, it was also important to look in more detail at the collaboration in software development. In the previous stage of research this activity emerged as being vital to the company, with much of the competitive edge relying on the development of new software to support the design activities. However, it is also a complex process relying on collaboration between a number of stakeholders.

5.3.1 Method

This aspect of the research relied more heavily on a traditional ethnographic approach. Observations and informal interviews formed the crux of this and time was spent working on or advising the design activities. Eventually involvement became more strongly linked to a particular project called InvesT, and time was taken to build a better picture of this project. This took the form of more interviews and document analysis.

What follows is a series of Vignettes and short descriptions that summarise some of the earlier experiences gathered during this phase of research, and reflections on them. Many of these follow on from initial ideas gathered during the first phase of this research. In addition to this, a case study of the project InvesT will be presented to give a more in depth overview of the development roles and processes.

5.3.2 The Role of Users

As has been highlighted in the previous sections of this document, users play a vital role in design. Their domain and procedural knowledge need to be represented in these tools, and their advice on the look and feel of the systems is also crucial.

Vignette 3 describes a meeting that took place fairly early on in this work and provides an example of issues that may occur when a user is not present to advise. It also touches on the issue of a user (who was not present) becoming 'too native' in the design team.

Vignette 3 - Interface Design Meeting

One of the meetings attended early on involved a subcontracted software developer 'T' who worked on the Airbus site for part of the week. Also in attendance was a member of the Methods & Tools team 'J' who was responsible for supporting the business side of the development. There was no 'key user' present at the meeting although one did exist (but was based in Germany). During this meeting the design of a search interface was being discussed. This interface would support users searching the database for CFD design records. There are a large number of these, and the naming mechanism is very complex, meaning that visual scanning is not feasible.

It was decided during the meeting that there was a need for both an advanced and simple search function in order to support people who knew the name of the file as well as people who needed to search based on other criteria such as when the file was created.

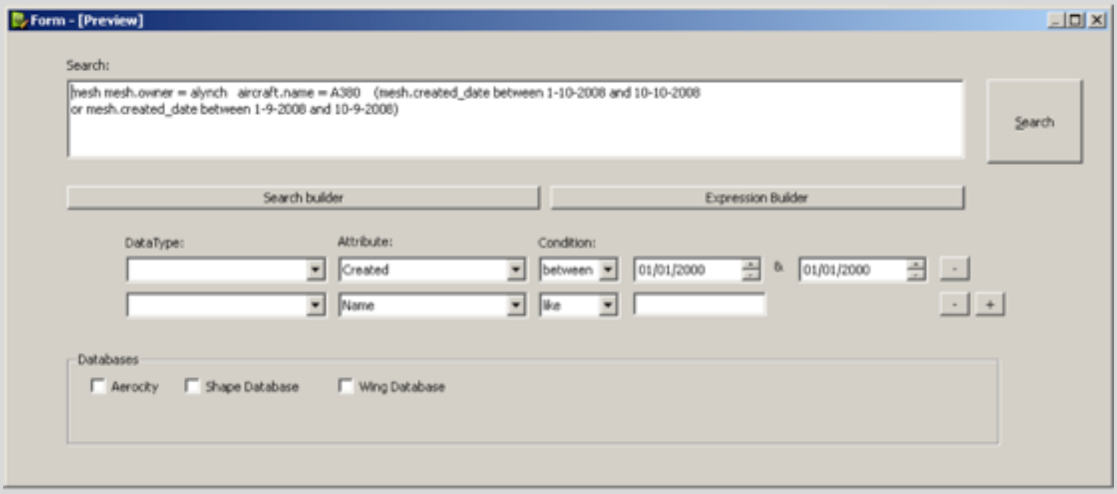

Figure 38 - GUI Mockup

During the meeting advice was sought on where buttons should be placed and what tabs should be named as. This was not something that was easy to advise on with so little knowledge of the user and domain. In software such as this, following generic design rules will not suffice. The expert knowledge lies with the users and key users who were not present. Whilst buttons can be made large enough, and spaced far enough apart, naming conventions and more complex procedural issues cannot be solved through the application of standard design conventions.

Whilst there was a key user for this system, discussion later revealed that they had begun to transition to a more technical role (becoming a 'native' to the design team). Whilst this could be a positive move and indicates the enthusiasm of the user towards the technical side of work, it also highlights a potential issue with PD practices, that of the user becoming proficient in the language of the development team. This can be an issue because the user is supposed to represent the language and activities of the user population and whilst they need to communicate with the rest of the development team, it could become problematic if they become too proficient in this. They may lose the ability to see the project purely through the eyes of the user.

Summary from Meeting

This meeting is a key example of the way in which users, whilst vital in the design process, are not always able to be present during key meetings. Their domain and process knowledge is key and cannot be represented through a proxy such as an interface designer. It is also interesting that the allocated 'key user' was becoming a native in the design team, moving away from the role of user. Whilst this may mean that they can understand the language of the design team, it may also cause the important naivety of the user perspective to be lost.

Reflections on Method

On a methodological level, this meeting observation highlighted the benefits of being able to take part in meetings as a participant observer. Through witnessing the expectations of the team, it was possible to realise the importance of the user in fulfilling much of this.

5.3.3 Collaboration

Collaboration within software development appears to be very different to that observed in the engineering teams. It is less formal and is also more visible in that it appears to happen more frequently and more directly. This appearance of greater frequency may be that planned and ad-hoc face-to-face meetings occurred regularly as opposed to the longer more formal design meetings seen in aerodynamic design activities. In the aerodynamic design much of the work is carried out individually, contributing to a shared goal, but over long periods of time. Within the software development process, the activities are much shorter and appear to involve more regular discussions.

5.3.4 Flexibility & Informal Processes

As time passed, it became apparent that tools and processes differed between teams and individuals. In addition to this, people used tools in their own unique ways in some instances.

Appropriation

Vignette 4 – Unexpected Appropriation of Technology

The software development teams use a variety of tools to support their work. One of these was Ploneforge, a Content Management System aimed at Software

Development Teams (although it is now no longer used). One feature is the Issue Tracker, used by developers to log bugs and track progress on them.

One of the members of the Methods and Tools team demonstrated how they used it to manage their work in general. When any task request came in (or they themselves thought of a task) they would log it as a bug, thus making it visible to others. They could then update it as they worked on it and change the status as and when it was completed. This team member had seen the potential of the bug tracker for making visible their progress on tasks, and had appropriated it for more general use.

This showed the importance to this particular team member of providing awareness to others of their work. It also demonstrated the importance of being able to appropriate the use of available tools to individual needs.

Key Observation
This 'flexible' and unintended use of the system is a key example of appropriation of the tool. The user was able to make use of a bug tracking system to 'track' their work. The visibility of the bug tracking meant that other people would be able to see their tasks. However, it is worth noting that this system is no longer officially supported.

This vignette highlights the flexible way in which a tool was used and appropriated. Over time it became clear that flexibility in system use, as well as roles, and processes, was a key feature of systems development.

Informal Artefacts

In addition to this, the initiative of people in the teams meant that 'informal artefacts' were being used, such as drawing project maps and assigning tasks to developers on a whiteboard (before photographing this and sending it around to the rest of the team – see Figure 39). M (the gatekeeper) turned this post it note plan into an MS Project Plan but noted that they still had to write on this later as things changed. Thus the flexibility of the whiteboard and post-it notes better suited the needs of the project.

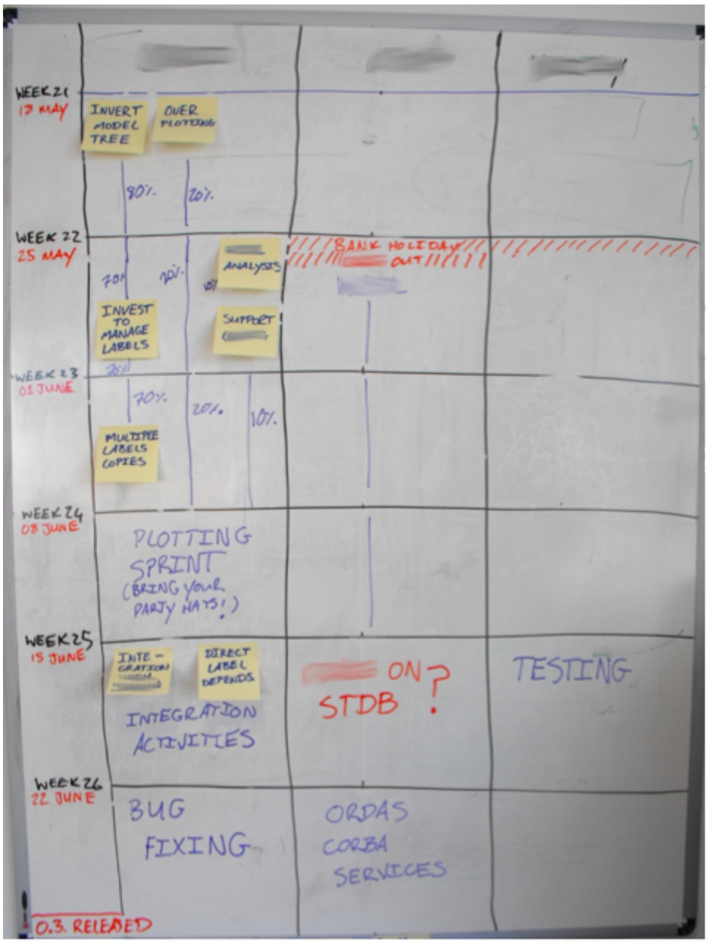

Figure 39 - Photo of Schedule (shared by a developer)

In another meeting between a developer, key user and Methods and Tools member, the developer listed design features on post it notes after the meeting, they then asked the user to prioritise these by laying them out on a table.

Data Storage/Repositories

Across observations of the software development teams, it became clear that a number of data storage repositories were utilised. These differed between projects but also changed over time. Initially some of the groups used PloneForge (http://plone.org/products/ploneforge), an open source content management system, to share documents and track bugs, but later teams were seen using another open source system called RedMine. RedMine (http://www.redmine.org/) is a project management web application that incorporates issue tracking, project planning, time tracking, wikis, and file management. In addition to this internally developed requirements management and 'collaboration portals' also existed.

In addition to these shared repositories, team members also used their email inboxes for storing key information (and these could be searched fairly quickly and efficiently).

The key interest within these repositories was the variability across projects and individuals as to what was used, with some projects and individuals preferring some systems over others. This led to a degree of 'fragmentation' of both formal and informal documentation. Whilst no direct 'breakdowns' relating to this were observed, there were often discussions between teams about which repository to use, as well as observations of people searching in a variety of places for documents.

Summary

These examples show how team members were keen to use their initiative to be more productive, working around the official 'constraints' of the defined project processes. The flexible use of tools and creation of informal artefacts allowed the teams to work in their own preferred ways whilst also adhering to the more formal project processes. However, this will inevitably require extra work to produce both.

5.3.5 Software Outputs

It could be suggested that some of the most successful outputs from software development have been those that have kept to a minimal design initially. One particular example of this is DesignCity. It was often referred to as a successful system. Vignette 5 describes this in more detail.

Vignette 5 – DesignCity Success

One of the systems demonstrated during early stages of the time at Airbus was Design City. During discussions with users and software teams, this system was referred to on a number of occasions as being a great success.

This vignette is taken from notes created after the system overview.

DesignCity was developed in 1999 using Oracle and Java. The development took a year, working in close partnership with a proactive user. The focus of the development was on building a robust interface for accessing and viewing data, to replace a command line system. Prior to the introduction of DesignCity the aerodynamic engineers had to know where they were sending their data to be processed and this is complicated as not all the machines are in the same location. In addition to this they were required to input or understand the details of the processing. Thus a system was requested that could hide this detail, allowing them to focus on the task at hand.

The system was developed purely in the UK, and initially was only used there. However it is now also being used in Germany.

When DesignCity was introduced it was done in stages. Basic functionality was introduced to the users and any reported problems were fixed before adding any new functionality. This seems to have resulted in the fairly simple system that it is today.

The system has a 'tree view' of data that users can filter. They can view a plane, its wing geometry, and relevant meshes that have been created. They can then set up variables for CFD analysis on the selected geometry (such as the angle and speed that the plane will be flying at). Once they run the analysis it can take a number of hours and they can run more than one job at once. The system can also be used to view the results of the analysis that can then be exported for use in other systems.

There are some bugs in the system but the users have learnt workarounds for these. For example if the view is minimised, the icons on the tree view get blacked out. But if the user presses Ctrl, Alt, Delete and then return to the screen this is fixed.

Success Factors
In comparison to other system development projects it was developed at only one location, and was for only one purpose. This allowed things like a 'tree view' structure of files to be hard coded. In other systems this view has to be flexible to allow users to alter the view depending on their role or purpose.

When asked about what made the system successful the developer felt that it was the way in which it hid the complexities from the users and simplified their work. If users have problems with the system they can speak to the developer face-to-face (there are only 2 users not located in Filton). This is despite a feature in the system for bug reporting (which is not used).

The fact that the system was developed and used by a single developer, in a single location, and implemented incrementally, appears to have contributed to its success. Future projects are being designed for use across all sites, and subsequently are also being developed across these locations. Not only do these have a more fragmented design team, but the designers also need to build a more flexible system.

The follow up system to Design City, had a much more formal development process and larger development team. This was necessary as the scale of the system was much larger and it was necessary to ensure that it would fit into the infrastructure. However, this project has been affected by a number of delays.

Points of Interest
This success story suggests that systems with a single developer, and a co-located set of users are much more effective. However, projects are now becoming larger, with a distributed set of developers and users. Whilst this is necessary to produce software that works in each location, it would suggest that there may be issues with the way in which teams are working together.

5.3.6 InvesT Case Study

During this phase of the research it was possible to get involved with a specific project. The gatekeeper M, was involved in this project as a 'Focal Point' for the system.

The system being developed was InvesT, which is used to take discrete 'spot point' data generated from wind tunnels, and convert it into a function that will represent it in future systems. It was also part of a bigger project known as Darius. This had a number of systems being developed which were dependent on each other to some extent. These systems were grouped into a 'work package'. The relationship between these can be seen in Figure 40 (a document provided by Airbus).

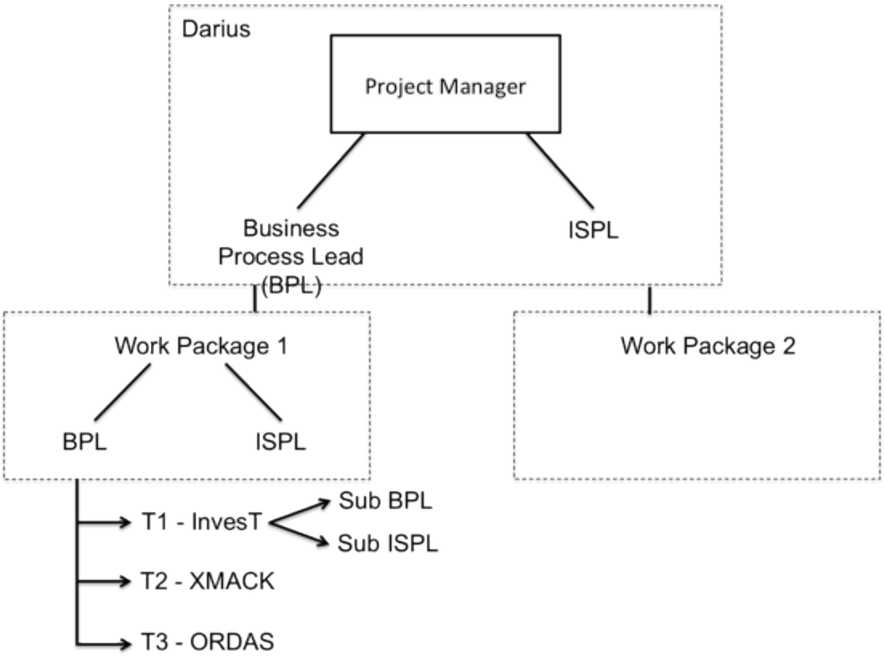

Figure 40 - Projects Overview

Project Roles

Figure 41 is a slide that was provided by M. It is useful as it highlights the roles, the work plan, and the meetings across an eight week development iteration. Although M pointed out that not all meetings were attended by all those listed (and not all meetings took place).

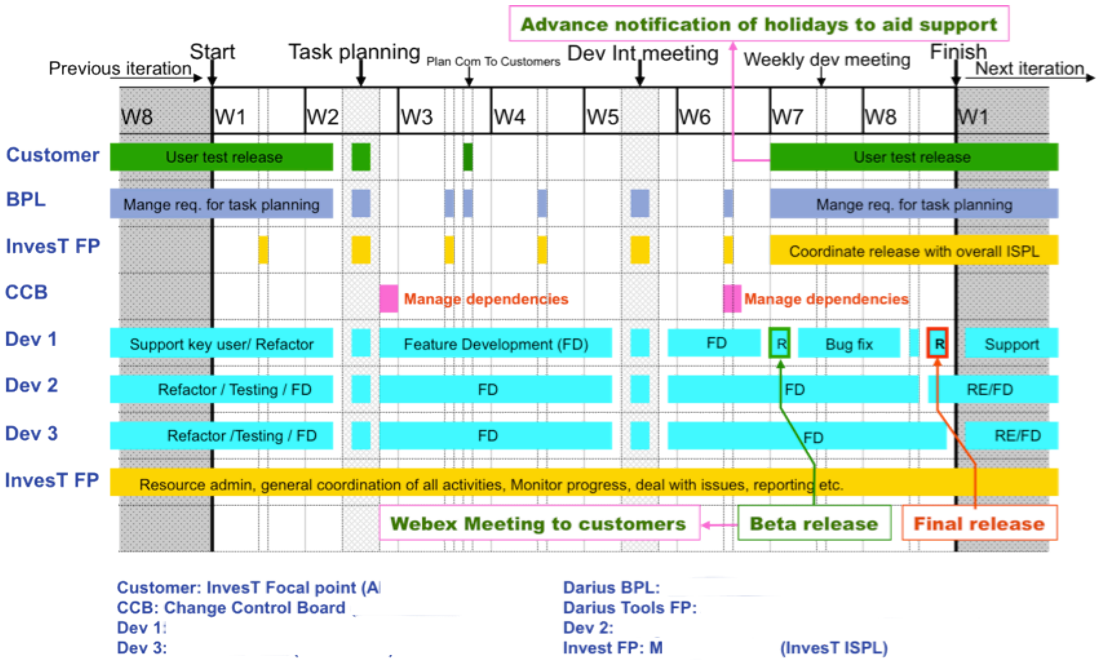

Figure 41 - InvesT Roles and Meetings

To further explain the diagram, on the left hand side is a list of the roles (with a bar representing the activities of this role to the right). These roles are as follows:

- *Customer* – This is what has been referred to as the 'key user'.
- *BPL* – Business Project Lead. This is a role similar to that of the key user, but is more management based. This is the person who provides advice based on the business processes of the users but is also responsible for cascading information. This role covers the entire work package that InvesT is part of.
- *InvesT FP* – This is the project Focal Point. They are responsible for the project management activities.
- *CBB* – The Change Control Board. This is made up from other roles in the team and is involved with ensuring compatibility and managing dependencies with other systems.
- *Dev 1,2,3* – The developers. Two based at SDC, and another in an equivalent development firm in Germany.

Tasks

The tasks and responsibilities are also listed in the diagram and these include User Testing (Customer), Managing Requirements (BPL), Release Coordination (InvesT FP), Managing Dependencies (CBB), and Feature Development (Developers). Many of these tasks consist of the management of the project and coordination of interdependencies with other projects.

Meetings

Figure 41 shows the intended meetings (represented by arrows at the top) and who should attend (the coloured blocks in these columns). The intended meeting attendance is summarised in Table 3.

Table 3 - Meeting Attendance

Meeting	Attendees
Task Planning	Customer, BPL, InvesT FP, Developers x 3
Plan Communication to Customers	Customer, BPL, Developers x 3
International Development Meeting	BPL, InvesT FP, Developers x 3
Weekly Development Meeting	BPL, InvesT FP, Developers x 3

As you can see, most roles are expected at nearly all the meetings, except occasionally when the customer/user is not required. The CBB also do not have to attend many of the meetings.

What isn't seen here is that daily scrum meetings take place between the developers, BPL, and sometimes the FP.

There are specific meetings for managing dependencies attended by the Focal Point from another project, the CBB, the BPL, the InvesT FP, the users and the developers. This is specifically designed to manage the dependencies with other projects that are part of the work package. This work package is a series of development projects that are dependent on one another. In fact, delays on these projects were impacting on InvesT.

Process and Documentation

The project has 2 monthly design iterations, which end with a release for testing with the users. Users detail requirements, which are collated and prioritised by the BPL. Through meetings with the BPL, ISPL, Developers, and Users these are transformed into prioritised User Stories which again have priorities. The work package manager is in charge of agreeing the priorities (along with the BPL). Everything is always communicated upwards to the Darius project manager and the work package BPL is responsible for this. During a planning meeting, plans are made for iterations and versioning. This has to fit in with the higher-level delivery plan for Darius.

The InvesT project officially followed (and complied to) the Airbus standard development process GPP (Generic Project Process) (see Figure 42). In this process requirements are established upfront for costing purposes and do not change.

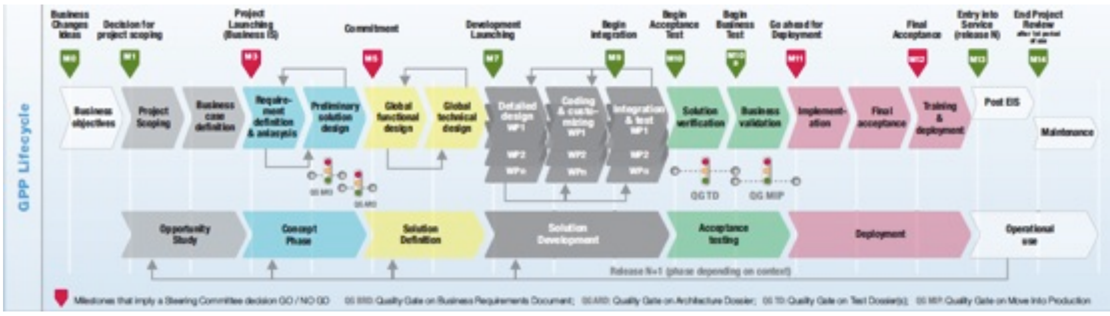

Figure 42 - GPP Lifecycle (from Airbus documentation)

Figure 42 is intended to show the high-level overview of what is a rather complex formal design process. Figure 43 highlights how the requirements definition is completed upfront before preliminary and detailed design. Early design has some iteration, but then requirements are finalised before the detailed design takes place. Whilst this is the official process for all projects, informally Agile development is used within some of the software development projects.

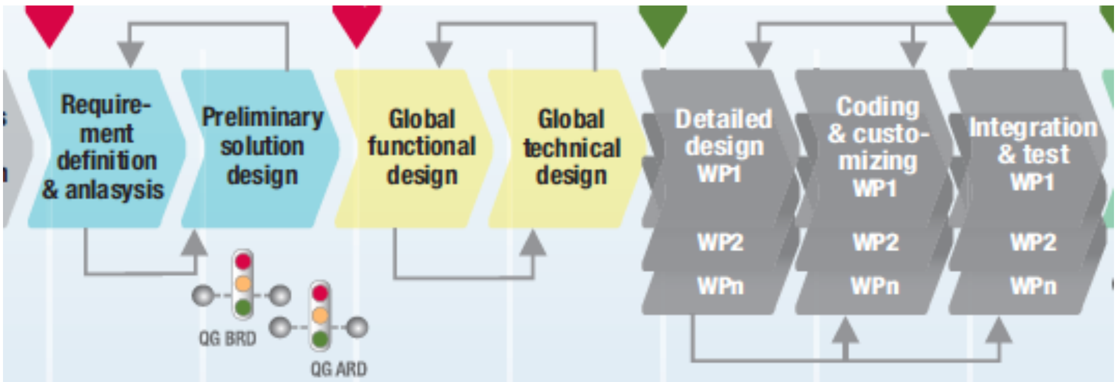

Figure 43 - Zoomed in Detail of GPP

Agile Development

Agile development is a design process based on short design iterations. Each of these produces working software and is used to gather feedback from users. Each iteration is essentially a complete but miniature project. User stories record what the user wants and if something isn't recorded in a user story it won't end up in the software. The user stories are flexible and may change up until the end of the project. Each development iteration tackles a number of prioritised user stories (Pilone & Miles, 2008).

Figure 44 and Figure 45 are UML diagrams created for the MSc component of this work that represent the development process (although this is not the formal GPP process). They demonstrate the process that is followed and the roles responsible for each of these. These are included as illustrative examples, and do not fully depict the complexities, and flexibility of the actual processes.

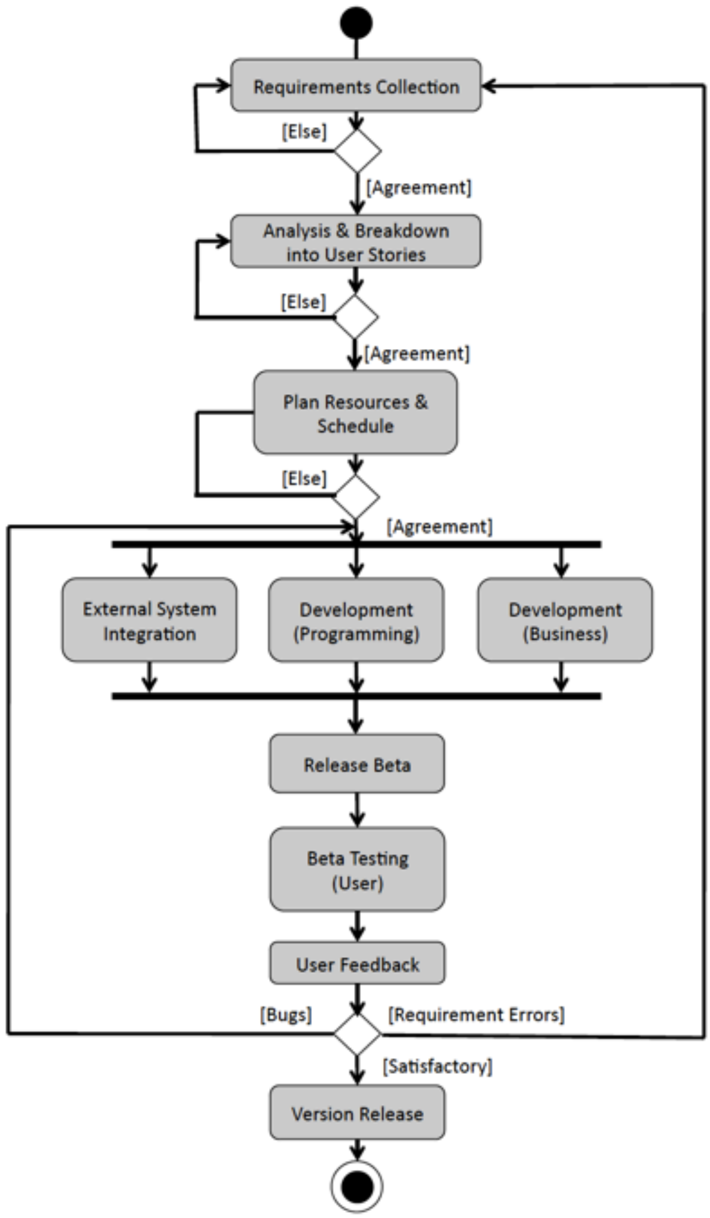

Figure 44 - UML Activity Diagram

The Activity Diagram in Figure 44 attempts to illustrate the process of development, from the collection of requirements to a final version release. After the team has agreed on a set of requirements, these are broken down into User Stories which again are agreed on before initial planning of resources and schedules for the development iteration. The development work is then split across the three development roles (External System Integration, Programming Development, and Business Development) and this runs in parallel. The development work is then combined into a Beta Release that the User/Customer tests and provides feedback on. If the testing is satisfactory, the new version is released; otherwise the process is repeated (with new requirements being collected).

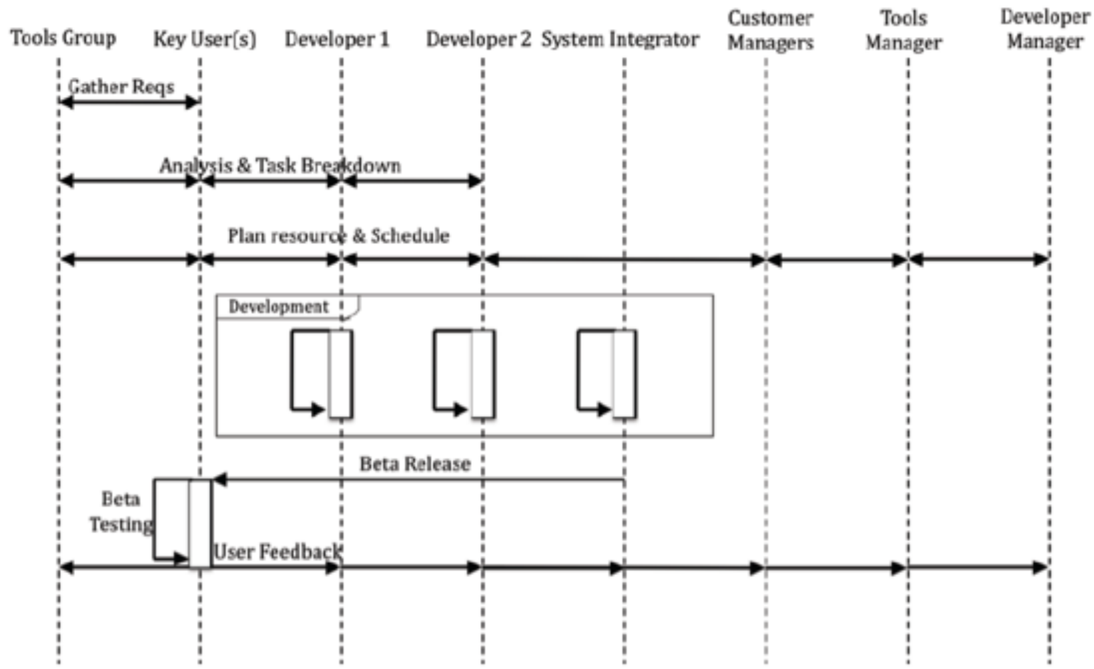

Figure 45 - UML Sequence Diagram

The Sequence Diagram in Figure 45 takes a different look at the same design process, this time highlighting the task responsibilities and communication between roles. Here it can be seen that it is the role of the Methods and Tools group and Key Users to gather requirements, before the Developers join them to analyse these and break them down into tasks. All roles (except for the Systems Integrator) take part in the planning and scheduling process, before the Developers and Systems Integrators carry out the development work. Users carry out the Beta Testing before providing feedback to all project team members.

It should be noted that the role names differ from those listed in Figure 41. Although in general the roles are very similar, the differences in title highlight the inconsistencies across projects (and even within projects).

Decision Capturing in Artefacts

Due to the need to adhere to the formal process, a number of documents need to be produced. However, in addition to this, more informal documents such as user stories are also being produced to support the agile development process. There appeared to be some issues relating to decisions not being captured effectively within this documentation. The following vignette provides an example of this.

Vignette 6 - User Feedback Session

This session occurred over WebEx with audio occurring over the phone line. Presence at this meeting was a last minute consideration. An attendee at the meeting (M) was joining in and thought that it may be of interest and so suggested this. In fact, this observation turned out to be very useful.

It was not possible to record the session due to difficulties with plugging recording devices into the phones, and the fact that consent could not be gained in advance. However notes were taken and it was possible to get a copy of the slides used after the meeting.

Within the meeting the user was providing feedback on the latest release of InvesT via a PowerPoint presentation being shared on WebEx.

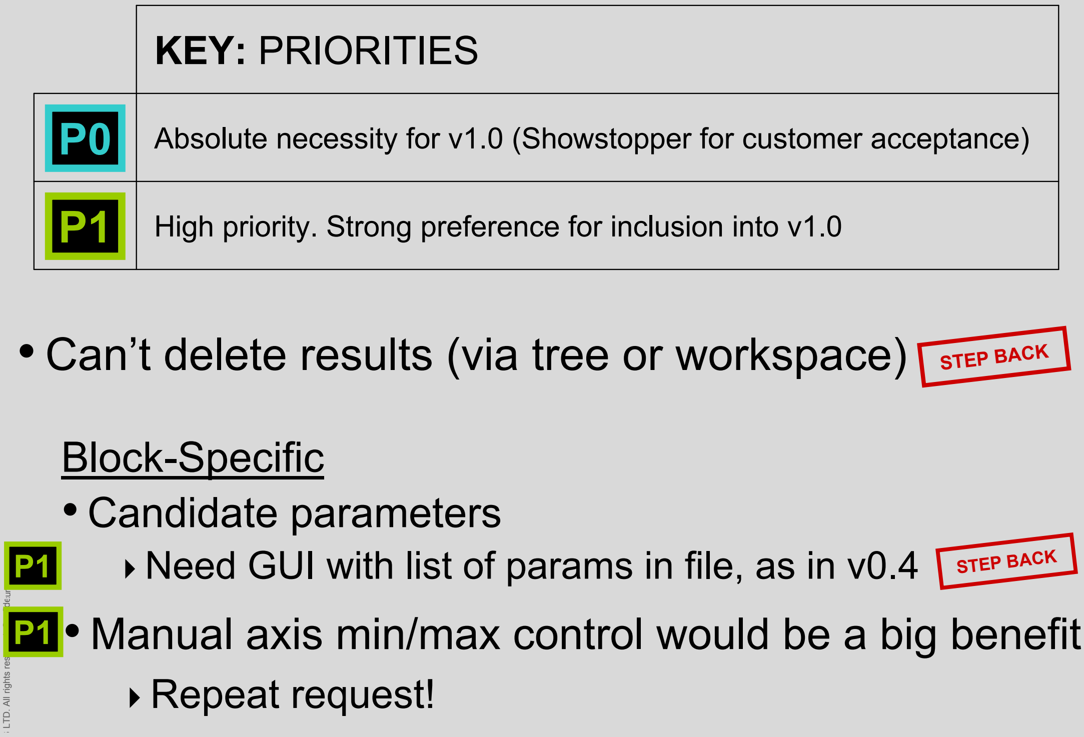

Figure 46 - User Feedback Document -> use of annotations

The user had used their initiative to structure the feedback in a meaningful way. They outlined the two priority levels of their feedback requests (see Figure 46) and then used images as 'stamps' on the slides to demonstrate this. In addition to this they also included another 'stamp' that stated when a 'step back' had occurred in the development i.e. something that previously worked as required but no longer did.

This 'step back' annotation, plus the presence of the text 'repeat request' (see Figure 46) shows that there appears to have been some miscommunication. The user seemed perplexed as to why the developers had removed or altered behaviours that they had previously been happy with and why their repeat requests had not being acted on. This may account for the reason why the user had taken the time to create very clear slides.

This issue of miscommunication was not an isolated incident, and others reported times when they felt that decisions were not being properly recorded. One particular informal discussion highlighted this person's belief that often a decision appears to have been made in a meeting, but in reality people have different understandings of this that are not revealed until a much later meeting.

5.3.7 Case Study Summary

The Invest project is a typical example of software development project at Airbus.

There are a variety of stakeholders in the project, each with their own priorities. This includes representatives from other projects who must ensure that interdependencies are managed.

Figure 47 – Case Study Overview

The team use a variety of communication mechanisms to keep in touch, such as face-to-face meetings, email and teleconferences. Many of these are ad-hoc and informal. Through this work they create a series of artefacts. Some of these, such as requirements documents are needed to adhere to the formal development process. However, they also create artefacts that are more specific to the agile development process they are following, such as prioritised user stories. On top of this they also create their own improvised artefacts such as post-it note plans.

These formal pieces of documentation as well as informal artefacts contain many of the design decisions that are made and discussed. These are stored in a variety of data repositories, including formal project management tools, email inboxes, and notebooks. As a result of this they become quite fragmented and cannot always be traced. In addition to this, some of the decisions made in ad-hoc informal meetings are sometimes never recorded properly. In a safety critical domain such as aerodynamic engineering, decisions need to be traceable. Not only is it important in ensuring efficient and successful software development, but investigations of future incidents may need to be traced back to software code. Therefore it is important that decisions are documented and stored in an accessible and traceable manner.

A number of issues appeared to be arising from this documentation fragmentation, and these will be discussed in the next section along with a more general reflection on the findings of this stage of data collection.

5.3.8 Output: High Level Needs

By this point in the research it had become clear that there were a number of key areas that could be better supported. These could be identified as 'needs' that are currently lacking in support.

Better Support for Sharing Domain Knowledge

Since the early ethnographic work it became common to ask the software developers what their background was as it was often not just computing. Examples of backgrounds included Physics and Engineering. In fact, a number of the software developers had moved into the development teams from aerodynamics. This strongly hints at how important domain knowledge (or at least a background in engineering) is within the software development process at Airbus. The developers often need to grasp difficult aerodynamic concepts in order to implement the systems.

Through both the study of the aerodynamic engineers, and the involvement in software development, it was clear that the complexities of the software, mean that the users (or a proxy for them) need to be closely involved in the development. However, the users are not taking part in the daily Scrum meetings and thus are not always being consulted regularly enough.

Support for Informal and Formal Documentation

The developers in particular are keen to make use of tools such as cameras, post-it notes, and whiteboards to create 'informal artefacts' to record decisions. The

SDC employees are able to take photos, as there are fewer restrictions about this in their workplace.

Whilst the projects officially follow a formal design process with set documentation and milestones, more informal documents and artefacts are being used in conjunction with these. These range from very informal post it notes to more formal user stories. These are required to support the more informal and flexible processes that are taking place within the development teams. However, are there conflicts between these and the more formal documentation that is required and does this introduce inefficiencies?

Improved Traceability

As has already been discussed, there appear to be issues with the recording of decisions. Informal chats with M also touched on this topic, with discussion of misunderstandings occurring after daily SCRUM meetings. It was suggested that whilst the teams were agreeing on decisions, the actual understanding behind these had been interpreted differently leading to problems later. It therefore appears that there should be better means of tracing and recording the rationale behind decisions.

Support for Development of Shared Vision

Misunderstandings appear to stem from a lack of shared vision. Stakeholders are forming conflicting visions of the design and thus making incorrect assumptions based on this. What is it that is leading to these issues? Does it relate to the communication mechanisms, the complexity of the work that they are supporting, or the ways in which decisions are being agreed on and recorded?

Support for a Variety of Communication Mechanisms

The teams tend to use a variety of communication mechanisms, including face-to-face meetings, emails, and teleconferences. There also seem to be occasions when regular communication is not happening. Is the fragmentation and occasional lack of communication also contributing to misunderstandings?

5.3.9 Reflections on the Method

Whilst the studies of aerodynamic dynamic design took a more structured approach to data collection, the studies of software development were more informal. It was possible to take part in meetings not just as an observer but also as a participant at times (i.e. taking an active role in the meeting as an HCI advisor). Whilst both methods drew insight, and the more informal data collection was less quantifiable, the studies of software development seemed to draw out ‘needs’ or areas for support more naturally. It was also easier to carry out this data collection, as the participants did not need to give up time for interviews or diary studies. Instead through active participation, mutual benefits could be gained.

As mentioned in the literature background, ‘going-native’ can be a problem during data collection of this variety. This did become problematic when input into projects was relied upon. For example, at one point it was possible to take part in a development project as an interface design advisor. This involved creating a requirements document, which can be a time consuming process. However when this begins to detract from other research commitments it can be a problem. In this situation it also coincided with a period of time away from the company (which wasn't uncommon) which meant that it was necessary to request to 'leave' the project as continuing whilst away was not feasible. After this it was important to maintain suitable boundaries. Whilst participation in meetings and short-term commitments was useful, becoming a dependable member of the team with deadlines and key responsibilities could detract from the research.

However, this is different to the involvement in the case study, where familiarity with the project team, the system functionality, and the processes was gained without taking a direct role in the project. Instead it was possible to attend a number of meetings, occasionally commenting in an advisory capacity on interface design. Through building up familiarity less time had to be spent on explanations and it was possible to attend meetings at very short notice and without causing disruption.

5.4 Next Steps

At this point in the project, it was necessary to narrow down the focus of the project, to concentrate on the specific needs of collaboration in one of these areas (aerodynamic engineering, or software development). The time and resource limitations of this research meant that not all avenues could be pursued, despite interesting features being identified in both areas.

Whilst it had been possible to identify key features of collaboration in both of these domains, the needs appeared to be greater in software development teams due to the inherent flexibility of the processes, as well as the need to exchange knowledge frequently. The prominence of software development also meant that effort should be spent in improving this process. By focusing on this process, knock on effects should be felt within aerodynamic design, as it is dependent on the outputs of the software development. In addition to this, it was an environment where potential interventions could be trialed without a huge procedural upheaval as might have been the case in the more formal aerodynamic design environment. This was an important consideration given the constraints of this research (time, budget, and resources).

However, the findings from the studies of collaboration in engineering design provide a background to the domain in which the resulting software is used, as well as the context in which the key users work. These are vital to aiding the understanding of software development.

This phase of the research process allowed different techniques to be trialed and reflected on. In addition to this it narrowed down the area of focus to 'Collaboration in Software Development' and produced a list of 'issues' to be further investigated with future work. The next chapter will discuss how this was achieved.

Chapter 6

Broader Investigation

6.1 Introduction

After the initial stages of ethnographic work a number of key 'issues' had become visible within the software development process. Whilst an in-depth view of the software development process had been gathered it was felt that as this was predominantly based on a single project case study and solely in one geographic location, it was important to also investigate some of these across a broader group of stakeholders. In addition to this, there were some areas that a brief literature review suggested would be issues that hadn't arisen thus far. Therefore these would also benefit from further investigation.

It was decided at this stage to use a less in depth technique that could be applied across a broader population and different roles, projects, and countries. This was down to logistical reasons such as not being able to travel to other sites, along with the feeling that a quick and dirty approach would be enough to provide 'support' for the initial ethnographic findings. Whilst a survey may not provide the depth of information that ethnography will, it is a way of triangulating the findings. Triangulation, within the social sciences, is known as the mixing of data or methods so that diverse viewpoints can cast further light on a topic (Olsen, 2004). By surveying other stakeholders from a broader perspective, it may be possible to further understand and probe the issues identified in the previous work.

This chapter will discuss how a broader investigation of the identified areas of focus (as well as additional points from literature) was carried out in order to further strengthen the initial findings. This lead to the development of a high-level set of requirements for collaborative support tools and these are detailed later in the chapter.

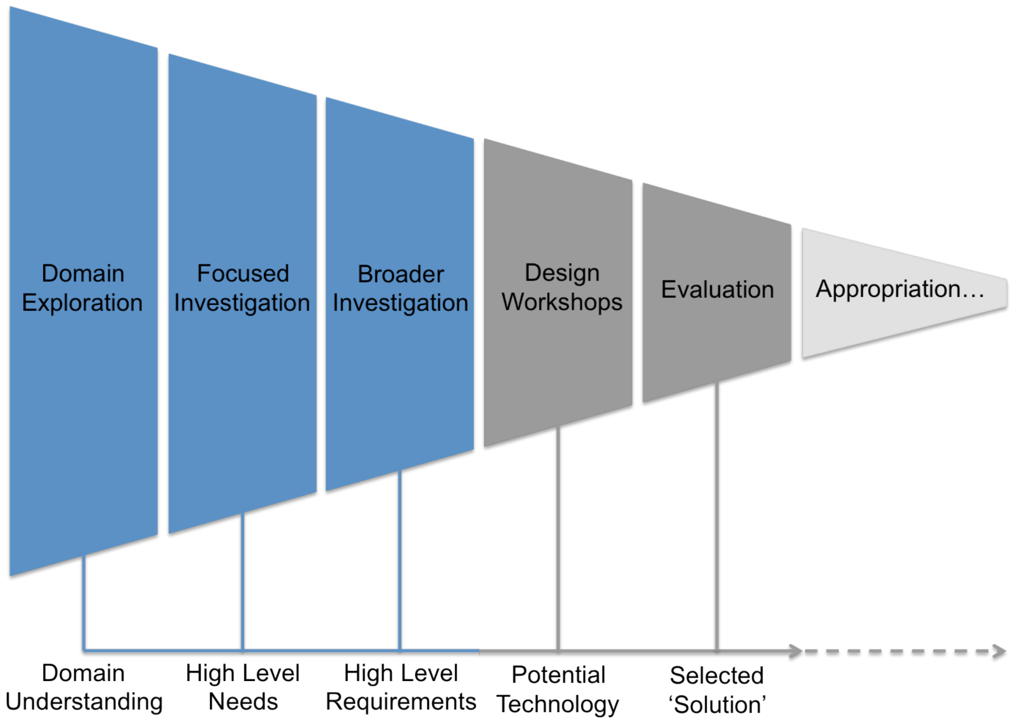

Figure 48 - Stage of Research Process – Broader Investigation

6.1.1 Method

In order to achieve this broader investigation, a short survey was designed based on the areas previously discussed. It mostly utilised open-ended questions although two Likert-type scales were included in order to gain additional quantitative data. The full survey can be found in Appendix A.

Initial questions gathered information on location and project role. Then two statements were included (see below) which were followed by a Likert-type scale asking how much they agreed or disagreed with them. They were also asked to provide reasons for this in open-ended responses.

'The development team are able to work well together to produce successful software systems'

'The mechanisms for supporting team work are successful'

The wording was chosen to be positive so that it didn't appear too much like the survey was asking them to be critical (as this may have put people off from filling it in).

They were then asked about tools and processes, misunderstandings, the role of end-users, awareness, informal communication, and their preferred means of communication. Finally they were asked more generally about what does and does not work well in the development process.

The survey was sent out by email to around 100 employees who were all working in groups related to software development (this was through existing mailing lists). This covered most people involved in software development within the aerodynamics groups across Airbus. In total 14 replies were received. The response rate was somewhat below the expected average response rate to email surveys (Sheehan, 2001). This may be due to the busy roles of the people being targeted or the particular dynamics of the organisation. Unfortunately it was not possible to expand the number of people that it was sent to, as this was the limit of the target group within the company. Follow up emails were sent, and this is what resulted in the final number of 14.

In particular there was little response from employees in the external SDC. Email exchanges with the manager of this firm indicated that the low response rate might have been linked to the workload of the staff and the fact that it was perceived to be a long survey (it was two pages in length, and consisted of 12 questions). The manager instead suggested that interviews could be carried out with the team based on the survey. With only a day's notice, it was possible to interview six employees at the company (one who requested to not be recorded), spending around 15 minutes with each individual.

As a very early analysis of survey data had been completed at this stage, it was decided that some questions could be adapted for the interviews, and to take a semi- structured approach to the interviews. Thus further questions were asked about domain knowledge, user roles, documentation, and collaboration.

6.1.2 Analysis

The results of the survey and interviews were coded using a 'bottom up' approach working from the data itself. The aim of this was to identify key themes that were not covered explicitly within the questions (i.e. topics that arose in the responses) as well as categorising the question answers. The coding was done to assist a more holistic qualitative analysis that integrated the results with the earlier ethnographic work.

6.1.3 Findings

Table 4 provides an overview of the codes that developed through the analysis and the occurrences of these.

Table 4 - Interview & Survey Coding

Code	References
User Involvement	20
Face-to-face Communication	12
Inconsistencies and Differences	10
Misunderstandings	10
Distance Matters	9
Processes	9
Awareness (general)	8
Awareness of Others	7
Time	6
Collaborative Tools	6

To provide an alternative picture of the data, a Word Cloud has been produced from the transcripts and this can be seen in Figure 49. This shows the prominence of topics such as communication, projects, tools, and management (as well as the more obvious 'development').

Through analysing the transcripts and coding these, it was possible to identify some key themes. These tended to reflect issues already identified (as these were often the focus of the questions), but in addition to this some other interesting topics arose. What follows is a discussion of the key areas of focus, both extending on existing concepts, and introducing newer concerns.

Figure 49 – Surveys and Interviews Word Cloud

Domain Knowledge

Designing software to support complex engineering tasks can be a challenge for developers who don't possess knowledge of the domain. In fact, it is telling that several of the developers studied had worked in the domain as an engineer in the past (as has been previously discussed). During the interviews a developer with this background agreed that this domain knowledge made it easier to understand the needs of the users.

Interviewee 2: "It helps me to understand our users. I can also ask them less questions than I would need to if I didn't have a background, because I can understand their processes."

However, the majority of the developers involved in the interviews did not come from this background (5 of the 6 interviewed) meaning that this domain information would often need to come from the end-user.

Interviewee 1: "You often look to the users to describe what they're doing from a sort of engineering viewpoint, they describe what the engineering task is and what information they need.... They might be able to guide you in their workflows...".

However, over time they were also able to pick up the language, which aided their communication process.

Interviewee 5: "Now after a while of being here I have built up more knowledge of the engineering side of things. I think that's just helped….because you can go over to Airbus and talk to the engineers over there and…in their language you can understand what they're saying. I'm probably more interested in the engineering side than the software development side."

However, despite picking up enough of the language to converse with the users, it was not realistic for them to pick up the knowledge to the level that the users had, making them still a key part of the process.

Interviewee 1: "…obviously it helps if you understand the domain knowledge but you're not going to know it to the level they do."

Interviewee 5: "…what we normally get is a list of requirements that is probably more engineering speak than software speak so often we have to go through it and re-write the requirements in a way that we will understand…. I think what we should do is go through the requirements and help them re-write them so that we all understand."

Interviewee 3: "…you often look to the users to describe what they're doing...they sort of describe what the engineering task is and what information they need in order for that to analysis to happen but how you then map that onto a piece of software and a user interface is something that I think I wouldn't particularly look for them to do… they might be able to guide you in their workflows and stuff…"

Thus, rather than transferring this knowledge from users to developers, the user must work as a member of the design team as central advisors, detailing their processes and clarifying engineering rules. Their validation of the system at regular intervals is also critical.

Survey response 1: "I am continually asking for their opinion on GUI look-and-feel, engineering rule definition."

Interviewee 5: "I don't think they should just give us requirements and we go away and build something, because if we did that we would just build something completely different and … they talk in engineering speak, we're software speak and its so different. So yeah, getting them involved at every stage really."

Interviewee 1 "It's ideal that you do have them (users) because you can try and understand how they currently think and how the domain activities that the software is supporting work and need to work".

Whilst this domain knowledge should have been captured in the requirements, it is difficult to record. Tacit procedural knowledge can be hard to express, and difficult to represent, so domain experts have to check and clarify this throughout the development process. This requires regular communication between developers and users.

Interview 5: "It's certainly a collaborative thing and I think they (the users) should be involved at probably more stages than they are, and that's something we try and engage with them, to make sure they are involved more at key stages, and be part of the design decisions along the way as well."

Input from users is vital in ensuring that what the systems does and how it is used is correct and that it is compatible with their current work processes. Subsequently, sharing, representing and communicating their knowledge, whilst allowing them to work more closely with the developers, is a core challenge these teams face. However, establishing this type of relationship isn't always easy.

It is also important to note that not all respondents took this view of the user role. One developer saw their role as minimal and another felt that access to users wasn't going to solve all the problems (but did acknowledge the need to understand their activities).

Interviewee 4: "Well at the moment what I feel about the customers is that they are just to give this feedback about the problems. That's it. For me the role of the customers if just feedback and maybe new requirements."

Interviewee 1: "…I don't see having access to users is necessarily (pause), it's not going to answer all your questions I think… It's ideal that you do have them because you can try and understand how they currently think and how they, yeah, how the domain activities that the software is supporting work …."

However, the general consensus from the interviews, surveys, and ethnographic work, was that the user plays a central role in most system development projects, and the need for regular input from them is vital due to difficulties in expressing requirements and building shared understandings.

Access to Users

Survey responses and observations indicated that despite the importance of the user in the development process, it is not always possible to gain access to them.

Survey response 13: (When asked what doesn't work well) "Feedback from end-users due to their lack of availability."
Survey response 1: "This (requirements gathering) can be difficult, not least in acquiring the necessary amount of time and energy from customer domain experts."

Problems with availability here stem from the fact that the user's role as an engineer demands the majority of their time, as has been seen in the previous ethnographic observations. In addition to this they are not co-located with the developers meaning that communication is not as easy. In this situation, finding efficient remote communication mechanisms becomes crucial.

Additionally, frustrations with a lack of understanding on the users' side were also reported. Thus, software developers also need to have clear means of communicating their knowledge and constraints.

Interview 5: "I think sometimes its a limitation because they don't understand how software is written and I think you hear so many times "oh that won't take you long" but they don't really understand how to sort of architect software."

Another point that was made was that the environment is interesting as users are available, unlike when producing off-the-shelf commercial software, where users are more 'hypothetical'.

Interviewee 2: "...one thing that's kind of unique about this environment is that we do have all our users available for interaction. You know, normally you don't have this, you just ship out your environment, maybe get some feedback but we actually have our users available so I think it is very important to talk to them throughout the whole project, get their feedback and drive the functionality as it goes on."

This is an interesting characteristic that in many ways should simplify the developers' work. However, it also means that users become very closely involved in the work, and have a strong investment in the output.

Attitudes to Communication

Remote communication between users and developers is highly important, as is the communication between other stakeholders such as system integrators and other development teams. The survey probed the ways in which this communication takes place, and how satisfactory it is.

The survey responses indicated a general satisfaction with the mechanisms supporting teamwork. Out of 14 survey respondents 9 agreed with the statement *'The mechanisms for supporting team work are successful'*, whilst 3 disagreed and 2 neither agreed nor disagreed. Yet despite this perceived success, communication was cited frequently as a cause of a number of breakdowns in both survey and interview responses. Additionally, this has been a key observation in earlier work, with team members reporting frequent misunderstandings and miscommunications.

Survey 8: "Team members not communicating their work & not talking to or phoning colleagues, especially when in different countries, but can be just as true even in the same office."

Survey 12: "There are always misunderstandings and miscommunications. To my opinion this has mainly to do with the ability and willingness of people to communicate well..."

Survey 3: "Majority of projects not working well due to: many stakeholders, … poor communication…"

Interviewee 3: "They (sighs) think like, erm, 'Are you really sure that is the right set of data?' 'Yeah I am' er a week later it turns out that you wasted a lot of time because it wasn't the right piece of data. That kind of thing. Its stupid stuff…"

Some responses also hinted at dissatisfaction with some communication mechanisms. For example, using remote communication tools that are not as natural as speaking face-to-face.

Interviewee 5: "Erm, you think oh yeah that will be ok but when they're not there you can't just turn around and ask them a quick question and get a quick answer I suppose, you have to email them or call them which just makes it just a little bit more difficult really."

Preferred Communication Mechanisms

In addition to this, the types of communication mechanism were probed. Ten out of the 14 survey respondents said their preferred method of communication depended on the task. For example, the respondents listed the following tasks as being better suited to email:- *'discussing plans'*, *'instructions as it serves as documentation of the request'*, *'small well defined items as it provides a written record'*, and *'formal communications'*. Tasks cited as better suited to face-to-face included:- *'design decisions'*, *'formal agreement and deeper explanations'*, *'developing relationships'*, *'technical discussions'* and *'complex issues'*.

The task-dependent nature of communications appears to indicate that providing flexible communication options is vital, rather than enforcing specific mechanisms on the teams. It is also important to note that persistent forms of communication such as email are preferred as they provide a trace of discussions. These traces help to record the design decisions as well as the rationale behind them. However emails often get 'lost' in overflowing inboxes and are not always available to the entire team. The raw text of these emails is also open to a number of different interpretations.

Informal Communication

Ad-hoc, unplanned communication was recognised as being very important by the development teams. This is an unsurprising finding but it is something that can be difficult to support. Again, this backs up the previous ethnographic observations.

Survey response 9: "(Informal communication is) vital and significant. Every channel that exists conveys this stuff. It must be managed and recognised as a respectable part of the process and facilitated…"

Survey response 11: 'Even though unplanned communication is not recommended for efficient development, it is not avoidable in many cases. At certain times the developer may need more clarification during the development. In this case informal unplanned comms plays a very crucial role.'

Both formal methods of communicating and ad-hoc communication appear to be important in this context.

The reported breakdowns in communication may be due to the fact that design discussions are being made through these ad-hoc, informal communication channels, and are therefore not being adequately recorded or shared.

Design Artefacts

Design artefacts are externalisations that help teams to build a shared vision of the system being developed. They are also a key means of recording and communicating decisions. The formal artefacts used by the teams are more suited to the view of design as an upfront process, something that is becoming less accepted. These in depth requirements documents and architectural specifications are produced at the beginning of the project and used for costing and scheduling. It is understandable that companies will want to have an agreed design schedule upfront and a breakdown of the costs and this is likely to be the case in many software development projects.

Interviewee 2: "In any environment its very difficult to spec out software fully and estimate how much it will cost and then implement and deliver that to spec. This is what Airbus insists on doing because of how their finances are structured…Officially there isn't enough flexibility."

However, despite the use of these well structured, 'heavyweight' documents, the actual process being used by the teams is iterative and often agile, with design decisions frequently being changed and updated. As the previous section highlighted, this process is being supported by less formal design discussions that weren't being recorded. For example minutes are not being taken in daily team meetings.

Survey response 8 (user): (When asked what doesn't work well) "Better recording of assumptions and design decisions made outside of the spec. "

The decisions being made informally and outside of the spec need to be recorded in some way. Cumbersome documentation is not realistic in this instance, so more flexible 'lightweight' artefacts could be used to share ideas and record the rationale behind them. Whilst upfront requirements planning is necessary for project costing, more flexible design artefacts are needed that can be easily shared with the entire team to provide a record of decision making whilst also acting as a focus for discussion.

Barriers

It was also possible to get small additional insights into the problems with introducing technology at Airbus. One example pointed out that technology already exists to support the jobs of the engineers, so it can be difficult to persuade them to use something new.

Interviewee 2: "our users already have software that does everything they need to do because … they're able to do their job today. So software that we have to give them has to be an improvement on what they had before. They're quite picky about what they will actually switch over. We need to get them to say ok actually this was better, I'll switch over."

Interviewee 2: "...we came up with quite a good product but unfortunately because there was no support from the business side, the product is now sitting on the shelf."

This comment was interesting as it suggested that for a new system to be used there it would need to be pushed from the management side. However, this implies that there was no 'pull' from the engineers who the system was designed to benefit. This may be due to the fact that they already have tools to achieve their work.

Regardless of the reasons for this, the developers seemed slightly disenchanted by the perceived lack of enthusiasm towards the systems from both the users and management.

6.1.4 Discussion of Findings

The survey and interviews backed up a lot of the previous ethnographic findings but also highlighted some new areas. Through analysing the data along with the previous findings it was possible to identify a set of support requirements, and design features of these.

Software development has become increasingly agile, leading to higher levels of informal communication and users playing a larger role in the development team. Within Airbus the interactions with users are even more vital as they provide the essential domain knowledge such as engineering rules and process descriptions. Findings indicate that frequent informal design discussions are occurring between users and developers as well as the rest of the team, with inadequate support provided by existing formal documentation for recording this. These interactions are being carried out via email exchanges and phone calls and whilst these appear to provide sufficient support for the communication itself, decisions are often not being recorded or shared effectively.

Studies of collaborative software development across a range of domains have reported some similar findings over the last 20 years (as seen in section 3.12). But these issues are still being encountered by the design teams in this context. This implies that there is still a need for further support in this area, and with developments in technology, these could be better satisfied.

Any solutions will need to account for the complex nature of the design discussions and the need to share and discuss domain knowledge and work processes. Establishing ways to support informal processes provides a conundrum, as by better supporting the ad-hoc interactions, the informality may be lost. A way is needed to provide rich, yet informal support for these vital exchanges to ensure that key discussions can be traced.

At this stage it was proposed that any solution should be lightweight. By lightweight it is meant that simple yet essential functionality is provided without the complexity often seen in more task specific tools. A combination of lightweight artefacts (or the means of creating these) and a lightweight tool for sharing and discussing these could provide a solution. Artefact annotations and discussions could also be recorded to provide traceability. The teams should be able to share ideas and information quickly in a way that all team members can access and understand without being stifled by the formality and complexity of the support tools.

6.1.5 Findings Overview

Having carried out a thorough ethnographic study of collaboration in software development it was possible to establish a need for better support for the informal, ad-hoc side of the development process, with a particular focus on aiding traceability of decision making, as well as the importance of including all stakeholders in this. However, in order to feed this into the next step of design it was important to highlight the properties or features of a solution that would help to achieve this. These were as follows:

Lightweight

Any solution should be lightweight. By this it is meant that it should offer simple, yet essential functionality that can be appropriated by the users to achieve a variety of tasks. It should not be specifically designed for any particular task process due to the variability of these between projects and people.

Artefacts

Any solution should focus on supporting the creation and sharing of design artefacts, both formal and informal. Design artefacts are often created in an ad-hoc informal manner, such as sketches on pieces of paper during meetings. Sometimes these contain key domain knowledge and ideas. In addition to this, more formal artefacts such as requirements or systems specifications are also created. Any tool should support the creation and/or sharing of such artefacts between all stakeholders.

Traceability

Linked with the ability to create and share artefacts is the ability to support the traceability of design decisions, again, both formal and informal. It should be possible to identify the rationale behind decisions that have been made.

Multi-Purpose

Linked to the need for a lightweight tool, is the need for it to be multi-purpose. Software development has a number of different stages, and takes place in a number of different contexts (i.e formal, and informal ad-hoc meetings, co-located, and remote meetings). Any tool should provide support for collaboration in as many of these contexts as possible (Olson & Olson, 2000).

These features were also broken down further into a set of requirements that are listed at the end of this chapter.

6.1.6 Next Steps

It was also realised at this stage, that the needs could in fact be met by current technology. As Norman (2010) stated, often technology that could meet needs comes through innovations (as opposed to being driven by needs themselves). In this case, some of these issues have been noted in previous studies of software development teams, yet still remain a problem. Over time technological innovations have continued to evolve, and it may be that products now exist that could solve some of the problems being observed. There appears to be potential for innovations in both hardware and software to play a role in this. A number of new devices such as mobile phones, tablet computers, and other portable tools are becoming more common, and increasingly affordable. However, the stakeholders in system development (especially the users) may not be aware of some of these, or the potential that they could have in the workplace. It was therefore decided to carry out participatory design workshops that would help to establish the way in which technologies such as these could be used to meet the established needs. This will be discussed in more detail in the next chapter.

6.1.7 Reflections on Method

The process used during this phase of the research was much more focused than in the previous two phases. The data collected was interesting and it was useful to have some more concrete data to work with. However, taken alone this data would not be as useful. It was the combination of this data with the more in depth contextual understanding that was important for this research.

On a more logistical level, it actually turned out to be very difficult to get responses to the questionnaires. Despite keeping the questions to two pages in length the response rate was low. The manager of the software development company felt that it would be better to interview the developers, and this took less effort and preparation than the surveys once access was provided. This highlights the need to be flexible when carrying out data collection in the field. Only a day of notice was provided prior to carrying out the interviews, but they turned out to be very fruitful.

Overall, this stage of research allowed further exploration of the identified 'issues' across other projects and countries. It also provided further insight into the ways in which these could be overcome with technology.

6.2 Output: High-Level Requirements

At this stage of the research it was possible to begin to detail the needs and design features more formally as requirements. The following section details these requirements. These attempt to represent both the needs for support as well as the constraints that may have implications for a solution.

For each requirement a description is provided, along with the rationale behind it. In addition to this a priority level is given to each requirement to represent the importance of satisfying it. This priority is based on judgement and experience gained during the previous stages of this research.

The requirements will be expressed using the following categories:
Functional Requirements: these describe the functionality that the system is expected to provide

Non-functional Requirements: these are not directly concerned with the specific system functionality but instead relate to emergent system properties such as performance.
Domain Requirements: these are derived from the application domain of the system.
(Sommerville, 2001)

6.2.1 Functional Requirements

1. Support collaborative work that is happening both face-to-face and remotely.
   Rationale: Software development work is carried out in a range of contexts, such as face-to-face meetings, phone calls, and net meetings
   Priority: Medium

2. Support collaborative work that is happening synchronously and asynchronously.
   Rationale: Software development work is carried out both synchronously (at the same time) and asynchronously (at different times).
   Priority: Medium

3. Allow users to initiate system use at any time.
   Rationale: Not all decisions are made in pre-planned meetings, thus the tool should be easily accessible to record ad-hoc discussions.
   Priority: Medium

4. Provide access to the system in a number of locations (i.e. through portability)
   Rationale: Meetings are carried out in a number of different locations such as the Airbus and SDC offices.
   Priority: Medium

5. Provide the ability to capture a range of design artefacts across the design lifecycle.
   Rationale: It is important that the tool can be used across the entire design process to avoid fragmentation of the design rationale across a number of systems.
   Priority: High

6. Allow all stakeholders to create, edit, and share artefacts
   Rationale: With a range of different stakeholders taking part in the design, it is important that all members can access design artefacts created by the system.
   Priority: Medium

7. The system must support the capture of design decisions (both formal and informal)
   Rationale: There is evidence of breakdowns due to design decisions being lost or recorded incorrectly.
   Priority: High

8. The system must support the sharing of design decisions
   Rationale: Once decisions have been captured it is important that they can be shared with the entire team.
   Priority: High

9. Provide facilities for additional annotations to artefacts created outside of the system.
   Rationale: Design decisions are often updated or require comments to be made about them. In order to be compatible with existing practices, the system should allow artefacts from other sources (such as Powerpoint slides or notebooks) to be annotated or updated.
   Priority: Medium

10. Provide facilities for additional annotations to artefacts previously created using the system.
    Rationale: Design decisions are often updated or require comments to be added to them.
    Priority: High

11. Support the creation and sharing of informal design artefacts
    Rationale: Many decisions are made and represented in notepads or post-it notes rather than within formal specification documents.
    Priority: High

12. The tool should be compatible with existing work practices
    Rationale: Software development teams have existing tools that this system will not replace. However the new system should be able to work alongside these.
    Priority: High

13. Allow the end users to easily share their knowledge
    Rationale: It is difficult for the users to find time to provide input into the software development process (particularly their domain knowledge). Therefore it should be easy for them to access and use the system.
    Priority: Medium

14. The system should not enforce set processes on users
    Rationale: Processes vary across projects
    Priority: High

15. The system should not enforce set roles on users
    Rationale: Roles vary across projects
    Priority: High

16. Provide means for the design rationale to be converted into or used in the development of formal specifications
    Rationale: Airbus requires the creation of formal software requirements documentation and system specifications. The system should feed into this process.

Priority: Medium

6.2.2 Non-functional requirements

17. The system should be responsive and quick to load.
    Rationale: Meetings often happen in an ad-hoc manner so it is important that system use can be initiated almost instantaneously. It should also support the fast moving nature of meetings.
    Priority: Medium

18. The system should reduce the amount of software that needs to be installed on machines
    Rationale: Employees do not always have permissions to install software on their machines
    Priority: Medium

19. Avoid the use of cloud based storage
    Rationale: Due to data security the company does not support the use of cloud based storage that may be insecure
    Priority: High

20. Do not require access to WiFi
    Rationale: The company premises do not have a WiFi network for general employee access.
    Priority: High

21. The system should be compatible with inputs and outputs of other systems.
    Rationale: The software development teams use a range of tools and are likely to continue to do so. Therefore the system should be compatible with these.
    Priority: High

6.2.3 Domain Requirements

22. Allow users to create complex representations such as diagrams, graphs, and algebraic notation
    Rationale: Aerodynamic design frequently involves these types of representation and they are often used when explaining and sharing domain knowledge.
    Priority: High

Chapter 7

Workshops

7.1 Introduction

Having carried out ethnographic studies and surveys to identify potential 'needs' along with high-level design requirements it was possible to begin considering potential solutions that could satisfy these.

When attempting to meet system requirements, it is not always necessary to look to bespoke solutions. There are often existing 'off-the-shelf' solutions that may be able to satisfy these. Thus at this stage in the research it became clear that there were already a number of potential solutions available to the company, without the need to design and develop something in house. As Norman (2010, p. 42) states "the technology will come first, the products second, and then the needs will slowly appear." It was likely that innovations had already arisen that would meet the needs established during this research or that concepts could be taken from these innovations and products and adapted to create new tools. Thus, two options became clear. Firstly, to match existing products to the needs, or secondly if this was not possible, to adapt existing innovations and products to meet them.

The advantage of existing off-the-shelf products is that development time is reduced. As the previous chapters have shown, developing a system secure and reliable enough for use in an industrial setting would have been a time consuming and complex task. If an existing product could meet the requirements then the logical conclusion was to at least trial this technology in the work setting. At the very least, lessons would be learnt, and new requirements gathered.

However, matching these products to the requirements needed two forms of knowledge. Firstly an in depth knowledge of the work processes, and secondly and in depth knowledge of the technological possibilities that existed.

However, despite having carried out in depth ethnographic fieldwork, it was still difficult to judge how new technology would fit in with the particular work processes of users. Thus it was deemed necessary to look at ways of involving users in this decision. This stage of the research is shown in Figure 50.

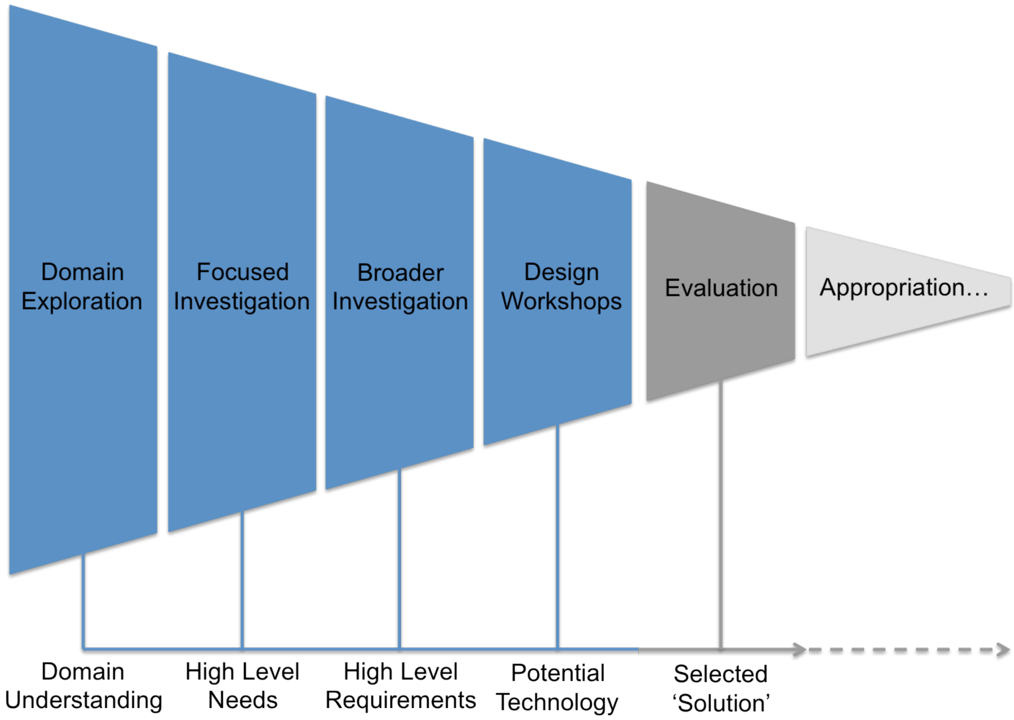

Figure 50 - Stage of Research Process

Key Considerations

Involving users in the design of their work processes and new technology is not a new concept. Participatory Design or Co-Design is an increasingly common stage of the development process and has already been discussed in section 3.6 in some detail. However, the concept of using the method to introduce new off-the-shelf technology is less well known.

Introducing Technology

The challenge in this situation was with introducing the workshop participants to the technology that was already available. A frequent criticism of PD is that "while users may be better (than designers) at perceiving the future conditions of work, they do not know what possibilities technologies are likely to offer." (Buur & Matthews, 2008, p. 188). Thus it is important to make them aware of these technologies.

There are a number of options to introduce technologies, including talks from product representatives, live demos of technology, and video previews. It was decided that the most feasible of these would be videos due to the lower cost (not needing to purchase or hire technology) and the ability to present the data in a less biased manner (which may occur with product representatives).

Today with resources such as product websites, YouTube adverts, and conference videos, it is possible to source videos easily. Thus a search could be carried out to compile a 'play list' of videos to show to participants displaying a range of videos. This could include more cutting edge technology, along with existing well-established technology.

However, one issue that needed to be overcome was the potential for participants to simply choose technology that fitted into their existing work processes. This would not be ideal as it might reduce the potential that the technology could have. Therefore, it was important to consider ways to get participants to think a little more 'outside the box'.

Open Minded Thinking

As Buur and Matthews (2008) state, innovation often requires people to envision possibilities that are not yet here. And as Nye (2006, p. 3) suggests, "Either to tell a story or to make a tool is to adopt an imaginary position outside the immediate sensory experience. In each case, one imagines how present circumstances might be made different."

It was important to help the participants to envision a new future with the technologies. One way to do this was to get them to rethink their work practices entirely, in an open manner, releasing them from the current constraints. By doing this, it was hoped that they would then be more open to imagining technologies supporting their work in new ways, rather than just supporting existing work processes.

In order to try and 'inspire' the participants, short videos were used. These videos contained 'blue sky' visions both in the domain of computing technology and outside of this. The rationale behind this was that through seeing future visions it would expand their thinking and provide 'prompts'. The selection of these sources will be discussed in further detail later in this chapter.

Combining with Ethnography

A further key feature with the design workshops was to incorporate the requirements and findings from the ethnography. Although the people taking part were aware of the domain and their work processes, it was important to try and incorporate the findings from the ethnography, which took a more objective approach to establishing 'possibilities' for support and key 'needs'. When presented with these insights they might not (and should not) have been surprised by them, these may not have been considerations that they would have explicitly realised themselves. In addition to this, the 'design features' came from an analysis that looked at requirements for meeting these within the context at Airbus. These are listed in Section 6.2. However in order to make these easier to understand and present to the participants in the workshops they were reduced to a set of 'design principles'. These were created by grouping the requirements into a set of higher-level themes.

Summary

With the decision made to carry out workshops to introduce technology, design features, and encourage innovative thinking, it was necessary to consider previous research in this area, and formalise the workshop design.

7.1.1 Background

Providing inspiration sources in group design sessions has been attempted in previous research. Halskov and Dalsgård (2006) (who are product designers) used *Inspiration Cards* in the form of physical cards with condensed technology and domain information (along with accompanying media in some instances) within design workshops. The aim of this was to present information from previous domain and technology studies to participants who would then combine this to form innovative design concepts. They found the approach to be a success with the design outputs forming a good balance between innovative and realistic ideas.

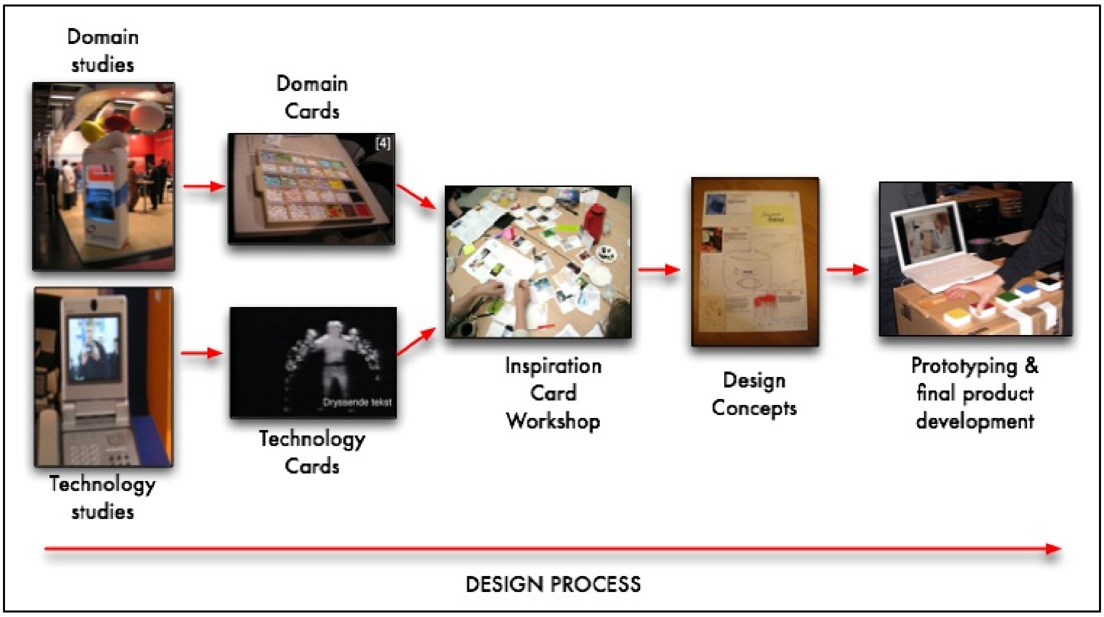

Figure 51 - Inspiration Card Workshop Process (Halskov & Dalsgård, 2006)

Marois, Viallet, Poirer, and Chauvin (2010) also tried to encourage innovation in PD sessions by using triggers in the form of introductory games, interactive illustrations and storyboards as a starting point for PD sessions.

Introductory Game

This involved the creativity technique of asking people to imagine a system to be used by a Martian to send photos from his trip to earth back home. This technique served the following purposes:

- An ice-breaker for the design group and helps foster a creative atmosphere,
- Introducing the concept of communications and content consumption on several devices,
- Suggesting a very different user perspective, beyond current well-established audiovisual and communication practice and systems.

(Marois, Viallet, Poirier, & Chauvin, 2010)

Interactive Illustrations

Instead of introducing working prototypes, interactive animated illustrations were used developed to simulate them and introduce the design issue being tackled in the workshop. These were Flash based sketches that users could interact with on a basic level by following instructions to move through the 'story'. Their role was to:

- Give a visual representation of possibilities,
- Engage participants in an active process,
- Generate ideas and provoke reactions,

- Invite participants to fix their design flaws,
- Suggest new possibilities altogether.

(Marois, Viallet, Poirier, & Chauvin, 2010)

One consideration by the authors was to present few details and highlight relevant items in the scenarios to ease comprehension, while also leaving ambiguities and thus room for interpretation.

Whilst being cheaper than introducing working prototypes, time and effort was needed when creating the illustrations.

Storyboards

These were constructed from screenshots of the interactive illustrations and served the following purpose:

- Engage participants actively, as they have to fill in the blanks between images to understand the story,
- Leave more room for interpretation compared to the interactive illustrations, users are free to imagine transitions,
- Propose a support participants can refer to,
- Allow written annotations to highlight specific items.

(Marois, Viallet, Poirier, & Chauvin, 2010)

The storyboards and illustrations appeared to be more engaging than the game. Greater bias was found with interactive illustrations as some participants only tried to develop ideas shown in the illustrations. However, the ambiguities appeared to stimulate questioning which was deemed a positive sign. The storyboards seemed to generate less bias and had the added benefit of being cheaper and quicker to create.

Future Thinking

Generating visions of the future in design workshops has been tackled before in the form of 'Future Workshops'. These were introduced by Jungk and Müllert (1987) for the purposes of involving citizens in public planning activities, but Kensing proposed furthering this use to systems development (Kensing, Halskov, & Madsen, 1991). The aim was to generate visions of the future and discuss how to realise these. Kensing, Halskov and Madsen (1991) then developed this into a more formal method, incorporating concepts from metaphorical design (using metaphors to stimulate reflection through seeing things in different ways). They propose a workshop with three phases, but with the researchers/facilitators spending time in the field prior to this (but only around a week). The phases are as follows:

Critique

This aims to draw out specific issues about current practices. It involves brainstorming to create short statements about current problems that are then grouped and reformulated by groups into a more concise critique.

Fantasy

The aim of this is to imagine 'what if' the workplace was different. It involves two warm up activities to stimulate imagination (inverting the critiques into positive statements, and drawings of the domain in 5 years). These are followed by another brainstorming session of statements of action for achieving a difference. These are voted on and the top ranking statements are turned into a 'utopian outline' for further discussion and development. This is when the facilitators introduce metaphors that they have created (based on their prior fieldwork) to prompt further discussion.

Implementation

This stage is designed to explore what resources would be needed to make realistic changes. Different groups present their developed 'utopian outlines' that have been inspired by the metaphors. The authors state an example where library workers, prompted with the metaphor of a meeting place, considered the use of the library as a place for conversations about books and suggested the creation of an e-bulletin board. These outlines are then evaluated in a plenary session to see if they can be implemented under current conditions or whether it is necessary or possible to establish new conditions in which to realise them. This is then turned into a strategy and detailed plans to be followed by staff.

This process is interesting as it attempts to prompt visions through critiquing existing processes, developing drawings of the future, and using metaphors to prompt reflection. It also looks at plans for implementing the actions in order to form a concrete output.

Creative Thinking

When looking at technologies for encouraging creativity Resnick (2007) looked at applying 'The Kindergarten Approach to Learning'. This involves phases of Imagine, Create, Play, Share, Reflect, and back to Imagine (see Figure 52). Resnick is a strong believer in iteration and states that "Iteration is at the heart of the creative process" (Resnick, 2007, p. 5).

Figure 52 - The Kindergarten Approach to Learning (Resnick, 2007)

This cycle shows the importance of imagining, creating, sharing, and reflecting. These are features that should be encouraged in the workshop design.

"Innovation often starts with a trigger: a new element made available that leads to new ideas, products and activities." (Marois, Viallet, Poirier, & Chauvin, 2010, p. 259). Visions of the future, and exposure to new technology, may act as triggers for innovation. For example, seeing new technology may lead people to re-imagine their activities being supported by this. This is the approach that Marois, Viallet, Poirier, and Chauvin (2010) took in their workshops.

Divergent and Convergent Thinking

Convergent thinking is a practical way of deciding among existing alternatives that may be useful when exploring the potential for existing technology. However, it is not so good at probing the future and exploring different possibilities (Brown, 2009). This is something that was vital to the workshops at Airbus. Divergent thinking can be useful in opening up options and creating more choices. And as Linus Pauling (winner of two nobel prizes) states: "To have a good idea, you must first have lots of ideas" (cited by (Brown, 2009, p. 67)).

It is important to try and stimulate both of these types of thinking in a 'rhythmic exchange'. Ideas emerge during convergent thinking, and choices are made during the convergent stage (Brown, 2009). The workshop design attempted to combine both of these stages of thinking and this will be explained further in the next section.

7.2 Workshop Design

7.2.1 Scenarios

If you are to develop something for people to use, you should probably take that nature of use into account (Carroll, 2000). Scenario Based Design (in an oversimplified nutshell) is a process in which design is refined through the development of 'stories' or 'representations' of situations (see Figure 53 for characteristics of scenarios). The design is achieved through creation of 'new' scenarios that incorporate any process changes of technological interventions. Scenario based design was appropriate for this situation as it was important to keep any design ideas grounded in the actual work of the development teams. This allowed for work process to be progressively re-envisioned and it was hoped that it would provide a concrete output that could be analysed by the facilitator.

To avoid intimidating participants with detailed explanations, the concept was used loosely. The main focus of the scenarios was to illustrate the people, systems and processes used within a work context. By asking participants to describe their new ideas in the form of the scenarios, it was hoped that they would consider the integration of these into the specific working context.

Scenario Element	Definition	Examples
Setting	Situational details that motivate or explain goals, actions, and reactions of the actor(s)	Office within an accounting organization; state of work area, tools, etc., at start of narrative
Actors	Human(s) interacting with the computer or other setting elements; personal characteristics relevant to scenario	Accountant using a spreadsheet package for the first time
Task goals	Effects on the situation that motivate actions carried out by actors(s)	Need to compare budget data with values questioned in memo
Plans	Mental activity directed at converting a goal into a behavior	Opening the memo document will give access to memo information; resizing one window will make room for another
Evaluation	Mental activity directed at interpreting features of the situation	A window that is too large can be hiding the window underneath; dark borders indicate a window is active
Actions	Observable behavior	Opening memo document; resizing and repositioning windows
Events	External actions or reactions produced by the computer or other features of the setting; some of these may be hidden to the actor(s) but important to scenario.	Window selection feedback; auditory or haptic feedback from keyboard or mouse; updated appearance of windows

Figure 53 - Characteristic Elements of User Interaction Scenarios (Rosson & Carrol, 2002)

7.2.2 Process

The main desired output from the workshops was a vision of how existing technology could be used or combined to support collaboration in software development teams. However to reach this stage, it was necessary to get the groups to firstly identify how work was currently done (to 'set the scene' and get them reflecting on their work). Secondly they would then need to be encouraged to think outside the box (using divergent thinking (Brown, 2009)). This was achieved through the 'Future Scenario' where participants were asked to envisage the future (50 years from now) where money and 'physics' weren't an issue. They were then asked to re-draft their scenario in this mind-set. The aim of this was to encourage them to step away from current processes, which may constrain their thinking. Finally the participants were asked to create a third set of scenarios where they attempt to achieve their future visions through the use of existing technology (using convergent thinking (Brown, 2009)). An additional stage was also used in the workshop but the details of this evolved over time, and this will be discussed in more detail later.

The Time/Space Matrix

One of the design concepts identified in the previous research was the idea of a flexible tool that can be used in different contexts. In order to help the workshop participants to be able to think about different contexts for tool use, the 'Time/Space" matrix was used. This is a common way of defining the different uses of groupware across time and space, and was originally devised by (Johansen, 1988). Interactions can occur in the same place, at the same time; in the same place, at different times; in different places at the same time; or in different places at different times.

Table 5 - Time/Space Matrix

	Same Time	Different Time
Same Place	Face-to-face Interaction	Asynchronous interaction
Different Place	Synchronous distributed interaction	Asynchronous distributed interaction

The use of the matrix within the design workshops described in this thesis was specific to the context being studied (although it may be useful in other contexts). The requirement for a tool to support a range of collaborative work across time and space meant that the matrix was a useful concept for encouraging participants to explore potential dimensions of use. Within the workshop the participants were asked to explore scenarios of use within at least one of the four dimensions of the matrix. They were then asked to expand the use of the tool to another dimension. Through this it was hoped that their ideas would be refined to become flexible enough for use across time and space.

7.2.3 Group Composition

It was decided that the design workshops should be group sessions in order to allow stakeholders to share their perspectives and ideas with each other. Resnick (2007) highlighted this process as being key in creativity, and it can also allow for greater reflection.

However, when you bring people together into groups there may be issues such as 'production blocking', 'evaluation apprehension' and 'free riding' (Diehl & Stroebe, 1987). This can lead to people being reluctant to share ideas or even unable to have their say. It is important to provide a voice to all stakeholders who may have different viewpoints. To try and avoid this, whilst still benefitting from group creativity, it was decided that the initial phases of the workshop would be individual, allowing all members to describe their current work practices. In fact, each scenario creation phase was individual, with opportunities for sharing and discussion after each of these.

Two video phases existed, firstly showing 'visions of the future' and secondly providing an overview of existing technologies. Figure 54 provides an overview of the stages of the workshop.

Figure 54 - Workshop Overview

7.2.4 Duration

The length of the workshops was a careful consideration. The longer the workshop, the more detail that can be considered. However to be a feasible technique in industry it needs to be short enough to ensure that management will encourage attendance. Given the domain under study and the time pressures involved it was deemed that anything that took up more than half a day would encounter problems. For this reason the workshops were intended to be two hours long, allowing sufficient time to work on and present the scenarios whilst taking up than less half a working day. As the workshops needed to take place off site (for recording purposes) this would also allow time for participants to travel to and from the event.

7.3 Workshop Preparation

In order to trial the method it was decided to hold initial 'pilot' workshops outside of Airbus. In total three of these were held as a way to refine the process and materials. The original intention was to run two pilot workshops, but the opportunity arose to hold a third and it allowed further refinement of the method.

A number of tasks needed to be completed before the workshops could go ahead. Firstly the *inspiration material* needed to be sourced. It was decided that the most engaging and efficient way to show the technologies to the participants would be through the medium of video. Thus this stage predominantly involved collecting videos of 'blue sky' visions of the future and demonstrations of current and near future technology.

7.3.1 Selecting Videos

Today it is possible to access a large number of videos through the Internet via YouTube and company websites. This meant that sourcing the material wasn't a problem. However the selection of materials from this huge repository was more challenging due to the pure scale of it.

The selection of materials was deliberately fairly random. This was in order to provide as little bias as possible. Whilst the scope of the workshops was 'tools to support collaboration' it was important to include tools that clearly supported this (such as video conferencing and social networking) as well as those that may not be so clearly used in this way (portable projectors, tablet computers etc.). This was done as there is potential for 'personal' tools to influence the way in which people collaborate. For example once cameras became digital it meant that sharing photos became a lot easier and thus people could use this to communicate more effectively.

Technologies judged to have the potential to meet some or most of the requirements were included but other technologies were also incorporated to try and avoid bias and also to ensure a range of material. This was based on the assumption that sometimes inspiration can come from sources that may not at first seem obvious.

Technologies at various stages of '*technology readiness*' were selected, from proof of concept prototypes displayed at conferences to tools that had been available to consumers for some time. It was hoped that the more conceptual tools may provide inspiration despite not being available to purchase. Videos collected personally at conferences were also included such as different tabletop and multi-touch surfaces to provide a more balanced set of resources (so not all were 'promo materials'). Clips of technology were kept short (around 30 seconds) to provide 'inspiration' without allowing the participants to focus too much on the details.

The Technologies

Some of the technologies selected included:

Microsoft Surface and Alternatives

These are interactive surfaces that respond to touch. Microsoft surface can also recognise objects through the use of visual codes placed underneath them. Each code will correspond to a particular object and the system will then know how to interact with it.

Alternatives that alter the technological implementation were also included, such as a frame that can be placed over any surface to make it touch screen.

These tools allow multiple people to interact with a computer system, often around a collaborative space such as a table. They offer a potentially more natural way to interact with data or information within a group setting.

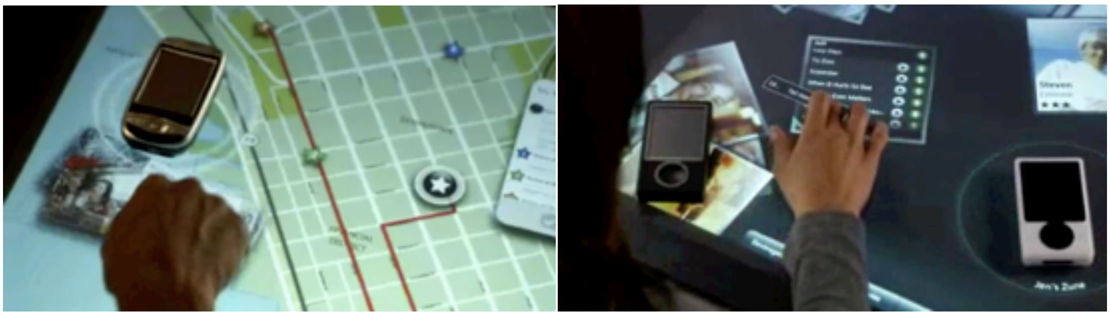

Figure 55 - Microsoft Surface Screenshots

Figure 56 - Touch Surfaces Screenshots

Microsoft Pictionaire

This is a touchscreen (projected) surface that also integrates physical objects by photographing them and then projecting them onto the table (Hartmann, Morris, Benko, & Wilson, 2010). It is a research prototype but could be re-created using off-the-shelf technology.

Much like the Microsoft Surface technology this system allows multiple people to interact around a table, often with the same objects. It is also interesting as it provides simple mechanisms for integrating digital and physical objects.

Figure 57 - Pictionaire Screen Shots

Pulse Livescribe Smartpen

This is a pen that digitally records what is written on special paper along with the audio. This can then be uploaded onto a computer to create a ‘pencast pdf’ which is a pdf of what was written, along with the audio. These can be played back to link the audio with the notes.

Whilst this may be seen as an individual productivity tool, the ability to create and share detailed notes, means that the tool can also support collaborative work. For example, pencasts are becoming a common way of sharing meeting or lecture notes.

Figure 58 - Pulse Smartpen

Tablet Computing

The iPad (and other android tablets) are a cross between a smartphone and a surface computer. Being around 7 - 10 inches wide they are portable, but provide a large interaction space. The tablets were also used to demonstrate augmented reality applications.

Like the Microsoft Surface, the multi-touch features of a tablet mean that a number of people can interact with it at once. However due to the smaller size of the screen it is more common for the tablets to be used individually. Like the Smartpen, tablets can be used to capture details of interactions (through audio and images) that can later be shared.

Figure 59 - Tablet and Augmented Reality

Flexible Surfaces

This is a product that is still at a concept phase. However it was included as it could provoke interesting visions. It is an e-ink display that can be bent, and these bends can actually be used for interactions such as turning a page. This is more of an individual tool, but as mentioned previously, some technologies without obvious collaborative uses were also included as they can still impact on the way people work together (i.e. if a device is more portable people are more likely to carry it with them).

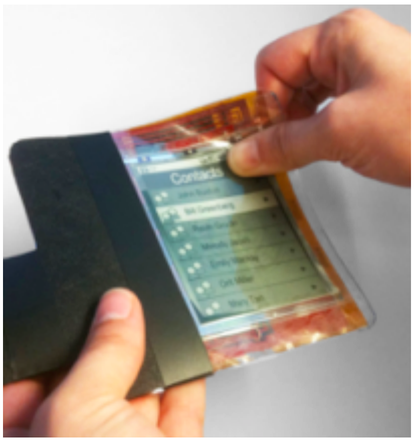

Figure 60 - A Flexible E-Ink Display

Data Visualisations

These video clips highlighted the ways in which people are now creating 'visualisations' of data in ways not seen before. This included a vision of flight paths across America sped up in time. Visualisations are an important collaborative tool as they allow data and information to be communicated more effectively to others.

Figure 61 - Flight Path Visualisation

Social Media

Social media was also included as an example of a collaborative tool traditionally used outside of the workplace. Clips included Twitter, and the use of hashtags, as well as a humorous presentation displaying stats about social media.

Portable Projectors

A clip from an advert for a portable projector was included. This technology allows users to project images 'on the go', thus providing a shared point of reference in ad-hoc discussions.

Smart Boards

Smartboards are a common feature in workplaces and provide an interactive surface that is mounted on the wall. Interaction with the surface is achieved through special pens. The video used in the workshops demonstrated the use of multiple smartboards in remote meetings. This can allow remote groups of people to work together across a large shared surface.

Dropbox and Google Docs

More traditional ‘collaborative’ tools such as Dropbox (a shared folder) and Google Docs (a shared document editor and repository) were also included in the video. These particular tools were not used at Airbus due to their limits on cloud storage but they were included due to the potential to provoke interesting discussion and possibly highlight the requirements for similar but more secure tools.

Visions of the Future

The inspiration material also included visions of the future from two companies. The first of these to be selected was from Microsoft and showed a vision of a variety of technologies such as mobile phones, newspapers, meeting tools, and augmented mugs. In addition to this a future vision from Airbus itself was used, displaying its new concept plane. This was chosen as although it does not address a vision of collaboration it may appeal to people from the same domain and inspire them to think more openly.

Airbus Vision

This video demonstrated the future vision of Airbus cabins and planes. This included invisible touchscreens for boarding assistance, conformable seats, and a transparent plane body.

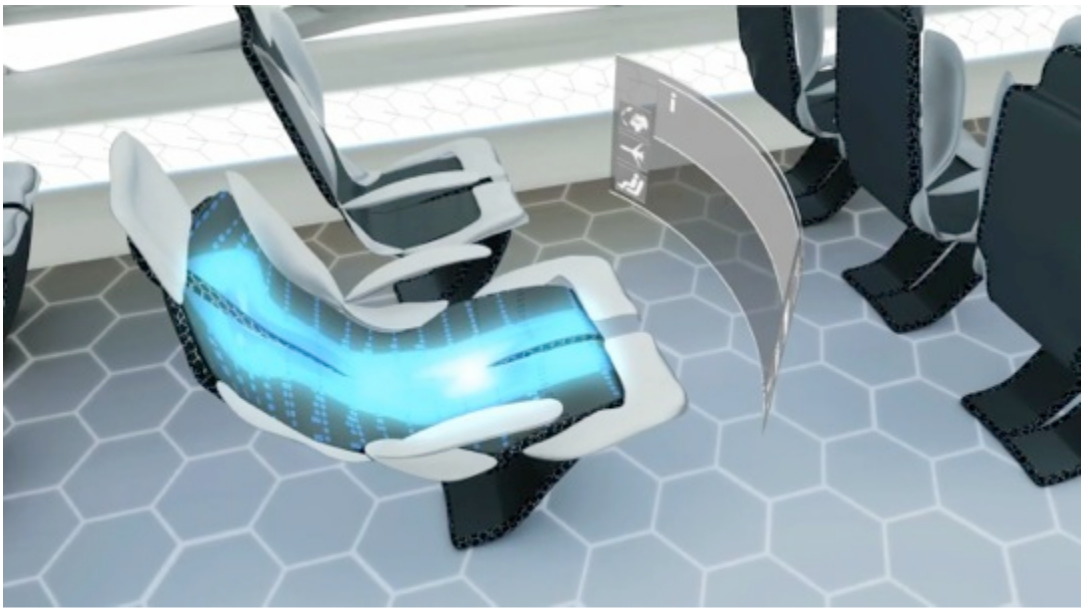

Figure 62 - Airbus Vision of Future

Microsoft Vision

This included clips from a number of videos released by Microsoft (and since updated) of their visions for the workplace, public spaces, communications, schools, and the home. Technologies included phones that projected a route onto the ground, tabletop technology that recognised objects, interactive newspapers, and transparent touch screens the size of walls. Due to the length of these videos, a selection of clips was chosen to represent a variety of visions.

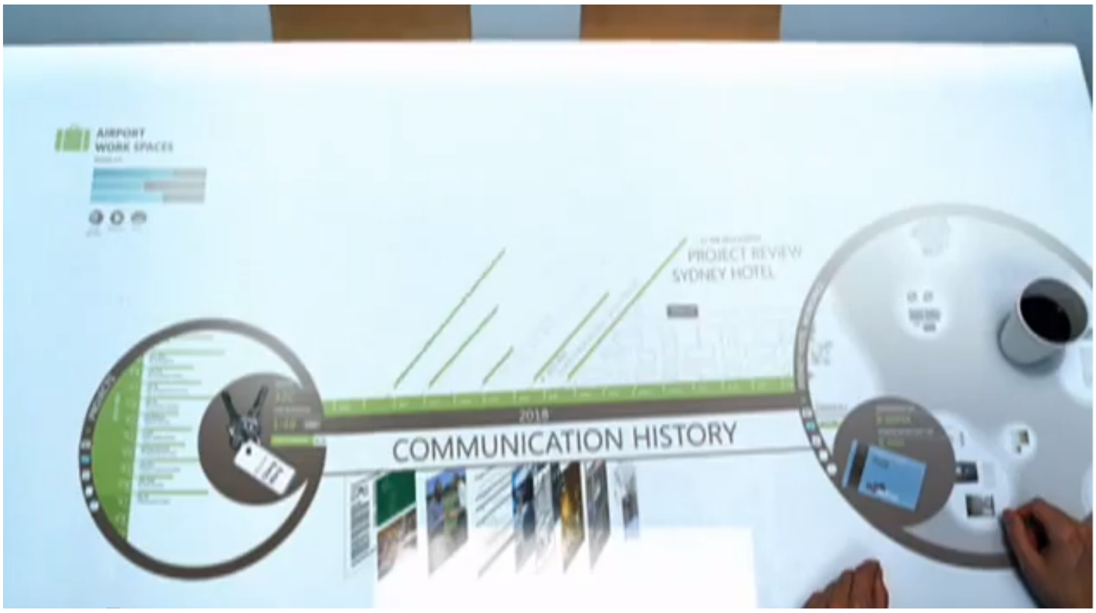

Figure 63 - Microsoft Future Vision

7.3.2 Technology Cards

Once the inspiration sources were collected the technologies were summarised on ‘technology cards’. The rationale for these cards was that they would provide a point of reference once the videos were complete and may remind the participants of the technologies. Halskov and Dalsgård (2006) used a similar idea in their Inspiration Workshops. The cards contained a selected screen shot to serve as a visual reminder, along with a brief description of the technology or category of technology (i.e. social networking). In addition to this, Quick Response (QR) codes were printed on the cards that linked to the original video when scanned with an app on a phone or tablet. This was to allow the participants to re-watch a video as well as demonstrating QR codes as a technology.

Figure 64 - Example QR Code

The QR codes were generated using an open source code creation system. This allowed QR codes to be generated and assigned to a web address. When read through the Barcode Scanner app (or others such as 'ScanLife') the address is opened on the device. A mobile phone with a large viewing screen (HTC Desire HD) was provided in the sessions for scanning the codes (although a tablet device could also be used).

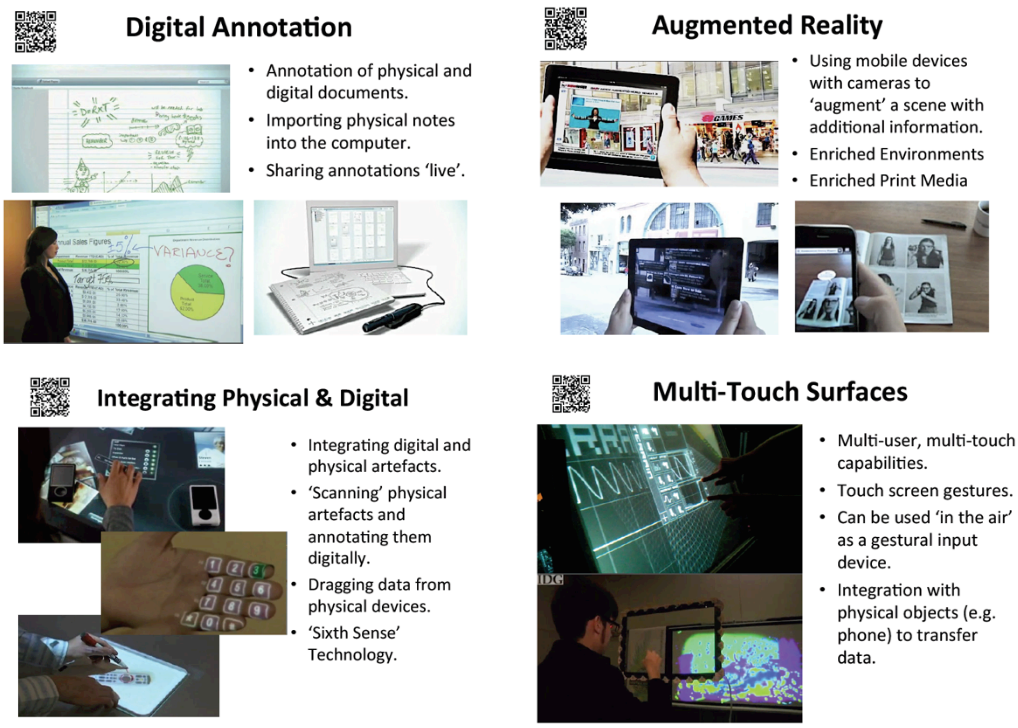

Figure 65 - Example Technology Cards

The cards were A5 in size and consisted of coloured card with a paper printout fixed to this. The coloured card was used to distinguish between technology cards (red) and concept cards (yellow) (see next section for explanation of concept cards).

7.3.3 Concept Cards

For the workshop held at Airbus the 'Concept Cards' were used. Each one represented a suggested design principle (or concept), based on the results of prior ethnographic work and served as a way of bringing the findings into the workshop for consideration by stakeholders. Whilst the design principles were presented as slides during the workshop, they were also printed on cards to serve as a physical reminder of the concepts. It was hoped that by presenting these concepts to the participants they would keep them in mind during their design work, thus allowing the recommendations of the ethnographic work to become incorporated in the workshop outputs.

The cards were slides that summarised the concepts (lightweight, multi-purpose, traceability and artefacts) where an informal visual icon was used to represent the concept alongside a brief description. The Concept Cards were presented on slides and briefly summarised after the last video session (the technology). Participants were asked to consider these in their subsequent scenarios. Again, the summary slides were printed onto A5 cards and given to the group. These were mounted on different coloured card (red) to avoid them becoming confused.

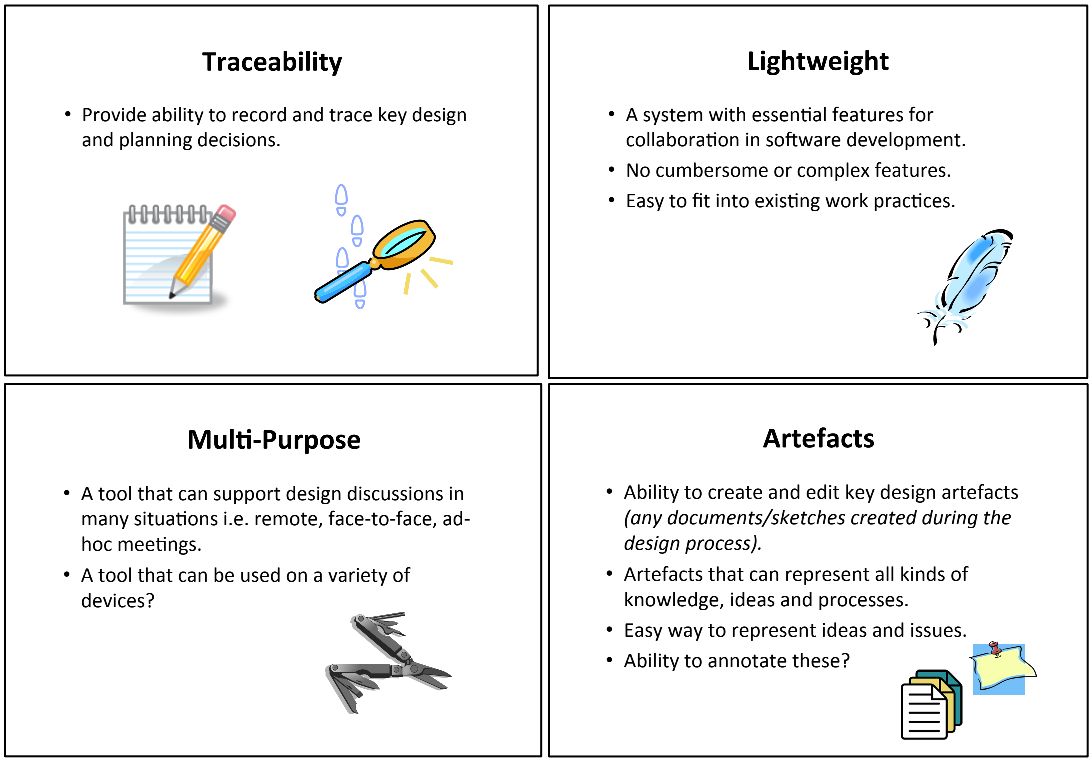

Figure 66 - Design Concept Cards

7.4 Workshop Process

The overall workshop process has already been summarised, but this section will go into the phases in slightly more detail.

Phase 1 – Current Scenario

Each participant was asked to describe their current work process and draw this on an A3 sheet of paper. To ensure a focus on collaboration, participants were shown the time/space matrix of collaboration and asked to focus on a situation that involved at least one of these. They were asked to focus on the people, tasks and tools involved. The group then took turns to briefly verbalise their scenarios.

Phase 2 – Future Scenario

The groups were shown a 5 minute 'vision of the future' video featuring the future visions of technology companies (sourced from YouTube). They were then asked to forget current constraints such as money and technology and think how they would like to achieve their task in around 20 – 50 years time. Once again the participants drew their vision and discussed it with the group.

Phase 3 – Technology Inspired Scenario

Finally the group was shown a 10-minute selection of clips of existing technology (both cutting edge and well established technologies, for example, tablet computing, augmented reality, data visualisation and social media). They were then asked to envisage how features of these technologies could be used fill the gap between their future vision and the current situation. Once more they were asked to draw their ideas and discuss them.

Phase 4 – Multi Context Design

The aim of this phase was to bring the designs together to form a single system concept that would support all the stakeholder views. The actual implementation of this differed between sessions and these will be discussed in turn later. The key rationale behind this session was to consider systems that may work in the wider context (either by supporting other collaborative contexts, or through supporting other people's collaborative processes). It was important, as a multi-purpose tool was a key design feature, and there would be little value in only considering a system that works in one context.

7.5 The Pilot Workshops

In order to refine the workshop process prior to using it at Airbus, three 'pilot' workshops were carried out. This section will describe each of these workshops along with analysis of the process and methods and the refinements that needed to be made. A final analysis of the method as a whole will be presented at the end of this chapter. It should be emphasised that the focus of these workshops was on the method being used, and whilst the scenario development is discussed, this is to illustrate the way in which ideas evolved. This design output of the pilot workshops did not impact on the technologies selected after the Airbus workshop.

7.5.1 Workshop 1

Participants

This workshop was held with three PhD students (T, R, and L) and one EngD student (Y) all at the University of Bath. The participants were recruited via email, and refreshments were provided along with £10 to thank them for their time.

Method

The workshop was designed to be three hours long but in reality took only two. It was held in the HCI laboratory at the University of Bath. Participants were provided with A3 sheets of paper (one for each scenario) and coloured marker pens. A small computer monitor (see Figure 67) provided the screen for the videos and slides. This wasn't ideal but it wasn't possible to get a larger screen working in the room that was used.

Figure 67 - Workshop One Setup

An outline of the session is shown in Table 6.

Table 6 - Pilot Workshop 1 - Procedure

Introduction   The participants were introduced to the concept of scenarios as well as an outline of the workshop. The groupware Time/Space Matrix was also introduced and they were asked to think of a work process that took place in at least one of these.
Phase 1   This phase involved the participants creating scenarios of existing collaborative work (in this case, collaboration in their research) then presenting this to the rest of the group.
Phase 2   This involved viewing 'Inspiration Videos' and the participants imagining their collaborative work in 50 years time, with no monetary or physical barriers. Once again these were presented to the group.
Phase 3   Participants viewed the 'Technology Videos' and were asked to imagine their work in 5 years time, inspired by the technology they have just seen. Again these were presented.
Phase 4   Here participants were asked to imagine the technology in their 3rd scenario being used within a different time/space context. Again these were briefly presented.

Analysis

At this stage the workshop was evaluated to establish the success of the workshop method and ways that it could be improved. Thus the evaluation helped to inform the design of the final workshop at Airbus. The session was recorded but transcriptions were carried out after the final workshop due to time constraints (the next workshop was only a few days later). However the output from the scenarios was reflected upon at the time as well as the responses of the participants in general.

Figure 68 - Scenario Presentation (left) & Video Watching (right)

Scenarios

The scenarios generated during the workshop were key to understanding its success. The next section will provide an overview of these scenarios and the way in which they developed. A full transcription of the scenarios from this workshop can be found in Appendix B.

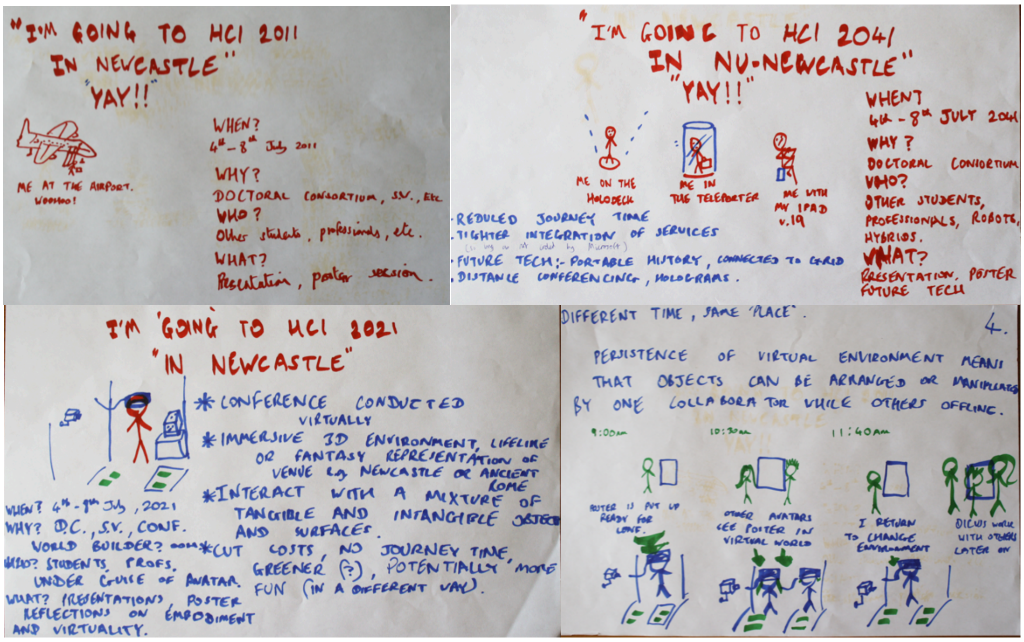

Figure 69 - R Scenario Development

R Scenario Development

R chose to talk about their upcoming attendance at a conference in Newcastle. Their idea mostly focused on the means of attending the conference with the initial conference travel being by plane. In their 'future' scenario this became teleportation. In the third scenario the conference took place in a 3D virtual environment that was carried out in real time using VR headsets. This was then adapted to a persistent virtual environment that could take place over different times, with participants entering and interacting with it whenever suited them.

The technology in R's scenarios appeared to mainly be 'inspired' by the technology presented, rather than using the actual technologies. For example, virtual environments were not included in the video material.

Y Scenario Development

R talked about their task of capturing expert knowledge within the company where their research was based. In their original scenario they talked about using tools such as bespoke semantic capturing software, spreadsheets, and notebooks.

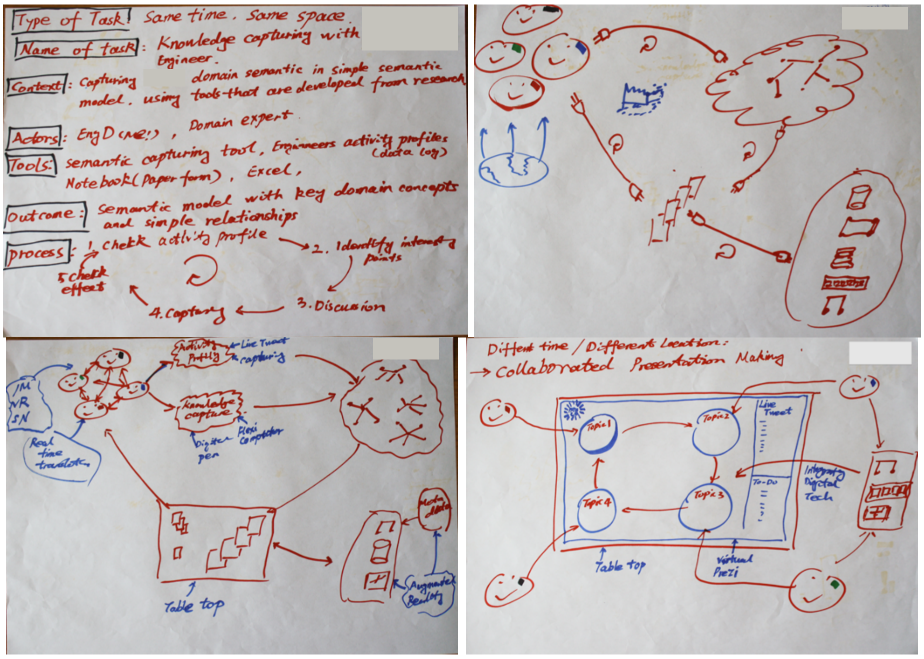

Figure 70 - Y Scenario Development

In their future scenario they talked about capturing this information automatically and consolidating it into concrete artefacts. They then also discussed being able to capture information from any type of source, such as old scrolls and books. In the third scenario (which they set in '10 years') they listed a number of technologies that could help them, including digital pens, social networking (both in the videos), automatic translation, and the semantic web. Through the integration of these technologies, they felt as though they could capture multiple models from individuals, rather than a group of users, "which is where we are at the moment". In their final scenario they actually chose a different task (creating a presentation) and they discussed using Prezi (not in videos) on connected multi-touch surfaces (in videos) along with Tweeting.

L Scenario Development

L talked about the collaborative task of editing a school newsletter with fellow researchers (they were working with a school). The school used email to share content with each other before putting together a final edit and sending it back and forth for comments. In their second scenario L described the team wearing 'magical watches' where they could edit the document in real time using voice recognition. They could then distribute the letter to schools and parents virtually.

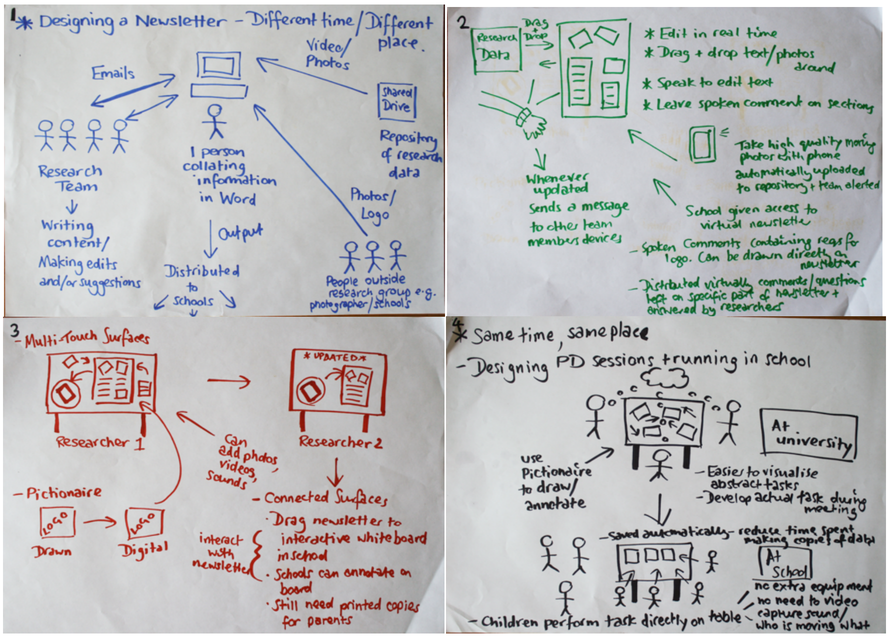

Figure 71 - L Scenario Development

In the third scenario L mentioned integrating multi-touch surfaces with mobile phones (seen in video). They specifically discussed the use of Pictionaire where logos could be drawn and turned into a digital version. They also mentioned connected surfaces being used so that the newsletter could be shared on a whiteboard for the pupils to see. However they said that printed copies would still be needed for the parents as "you can put it in the schools but if people don't have the right technology you can't share it." Finally, in the fourth scenario L moved this into a face-to-face setting where the researchers work together around the surface to build the newsletter in the meeting ("It saves time so you don't have to do it afterwards"). They can then take the table into the school to get the pupils to work on it too.

T Scenario Development

T chose to talk about running an experiment both face-to-face and remotely. In the face-to-face experiments T told the participants what to do. However remotely they did it via webcam (positioned behind the participant) in order to see what they were doing and check for distractions. In scenario 2 T talked about a neural interface for communicating with technology and people ("not unlike something from the Matrix"). T could use this to recruit participants instantly, tell them what to do, and record them (in great detail). T described sitting in front of "this amazing computer" analysing data just a day later.

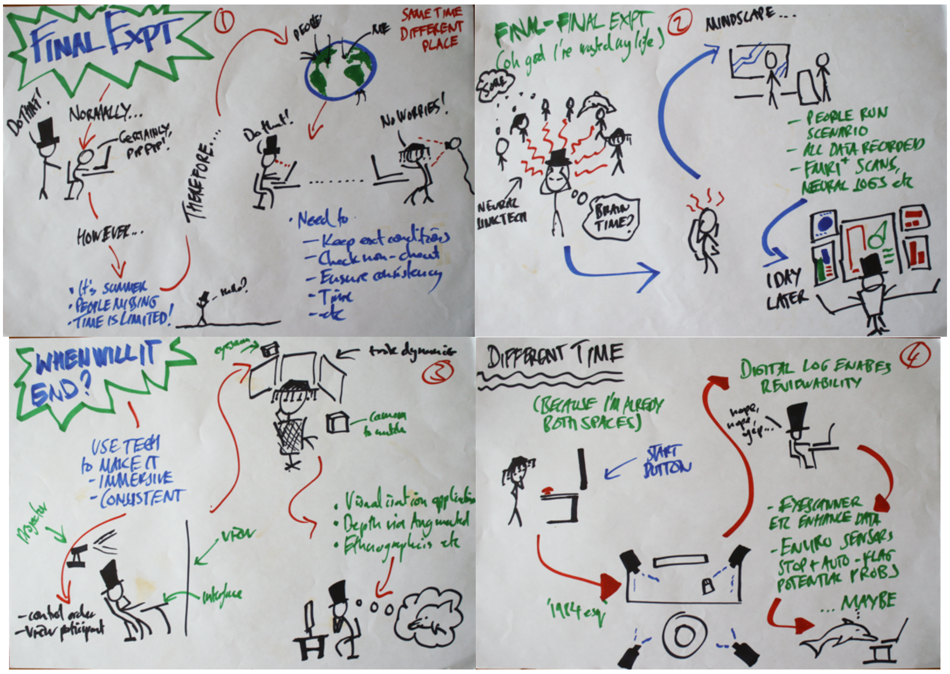

Figure 72 - T Scenario Development

In their technology inspired scenario T mentioned using some of the technology to make the experience more immersive. This included mini projectors (seen in videos), drag and drop interfaces, and touch screen ("to make it more ecologically valid"). They also mentioned eye tracking, which was not in the videos, for measuring gaze during the experiments. In the final scenario T imagined doing the experiment at a different time where people would wander up and press a start button. Here, control would be achieved through cameras and environmental sensors (not mentioned in video).

Scenario Development Summary

The scenarios selected initially were a mix between past events and future events as T and R had not yet experienced their scenarios. Whilst the tasks generally remained similar throughout the workshop, the future visions and technology ideas saw the way these were being achieved changing considerably.

When it came to the future visions all participants were able to come up with ideas that were fairly different to scenario one. R and T both kept the task similar but introduced an existing futuristic vision to help make this more efficient (teleportation and mind reading). Y kept the process very similar but more efficient and with less focus on a particular technology for achieving this. L introduced the concept of smart watches that radically changed the task of editing and delivering the newsletter.

When looking at the 'technology inspired' scenarios (both three and four) it was possible to see that some participants had looked at integrating the technology in the videos directly (such as Pictionaire, multi-touch tables, and smartpens), whereas others had used existing technology not presented in the workshop (such as Prezi, sensors, and eye tracking), and others had fused together concepts to form new ideas. For example R adapted ideas relating to Virtual Reality and 3D immersive environments to make a system for holding conferences remotely and L adapted the Pictionaire concept of connected surfaces to work remotely.

The important thing to note about these technology inspired scenarios is that many of the participants fixed their ideas 5 or 10 years ahead. This meant that often the technology wouldn't necessarily be feasible 'now' but perhaps in the near future. R mentioned this directly in their 4th scenario.

R: "We've got this technology but it's not this good....in 10 years it might be useful enough to actually do this."

When tracking designs across the scenario phases the development of ideas could be clearly seen. Concepts from the future vision were being partly achieved through existing technology. For example, T wanted to be able to conduct their research studies remotely rather than face-to-face using brain reading techniques ('brain time') in their ideal scenario. In the final scenario they accepted that this was not currently possible but they instead used cameras and eye tracking (a technology not included in the inspiration videos) along with data visualisation techniques to make the remote data collection and analysis easier (see Figure 73).

Figure 73 - Scenario Development

Overall there appeared to be more similarities between the participants' 2nd and 3rd/4th scenarios than between their original scenario. This suggests that they were able to successfully open their thinking. However even their 'realistic' visions in the final two scenarios were quite forward thinking.

The Workshop Method

This section will look at reflections on other features of the workshop and ideas for improvements to the method.

Scenario Creation

During the workshop there was some confusion initially as to the level of detail needed in the 'scenarios'. In response to this they were asked to provide the detail they felt necessary to get the point across.

T: "Possibly when it comes to describing it, I'm not worried about the task, it's the describing of it? I'm not sure to what detail or what level I don't know if anyone else is doing that."
T: "So in this case it's describing what you're doing, and in whatever way we think is appropriate. As long as we describe it?"

This may have actually stemmed from the fact that all participants were familiar with the formal concept of scenarios from their research backgrounds. They also wanted to know what to 'list alongside' the scenarios although this wasn't something that they had been asked. They were reassured that they just needed to get the idea across.

Y: "I can't remember all the key points of scenarios. The actor, the tools…"

Two participants also chose future scenarios for the first stage. These were things that they were about to be doing rather than had already done. They asked if this was ok and whilst it wasn't ideal it was useful to let them try this idea. However, in the workshop at Airbus participants would be strongly encouraged to reflect on existing practices.

Time/Space Matrix

The group decided amongst themselves during the first scenario to check that they weren't all describing tasks within the same time/space context. Although in reality this would not have been a problem the participants were concerned about it.

T: "We should probably all check that we haven't got the same slot in the matrix?"

In transferring their ideas across to other 'contexts' within the matrix, the ideas actually changed considerably. The idea behind the use of the matrix was that they might expand the idea of their technology to make its use more flexible, but the success of this was marginal as often the essence of the technology was changed.

Use of Resources

Within the workshop the participants could be seen searching through the technology cards and referring to these. However the QR codes were not utilised greatly and the participants tried to scan these with their own phones (this did not work as to codes linked to files on the computer being used, and required the phone to be on an ad-hoc network setup between a particular phone and the computer). In addition to this it seemed that the QR codes served more as a 'live demo' of technology than a way of re-visiting videos.

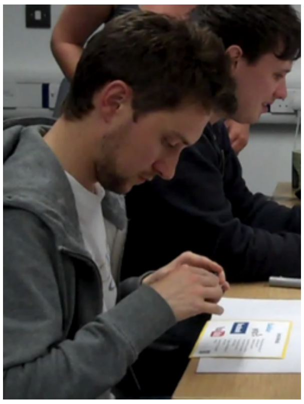

Figure 74 - Participant Using QR Code

Process Feedback

After the workshop an informal discussion occurred asking the participants how they found the workshop. Whilst there was some positive feedback, many of the participants mentioned the fact that it did not feel very collaborative. Three of the participants were familiar with Participatory Design and they felt that it was not as collaborative as these sessions would normally be.

L: It this supposed to be PD? Cos it's just that it's not that participatory…cos really we could have done this on our own and like there was no discussion, I mean obviously we could have but it wasn't encouraged and … I thought maybe at the end we'd pick one idea…"

Y: "On the plus side the way you get people to think outside of the box I think is good. The one video that projected the ideal scenario and the second video, it works it really works. They're great. But I think there is a lack of collaboration."

A couple of participants mentioned that they would have liked more sign posting about what was coming up in the workshop. This related to their original choice of scenario, as if they had known what was coming up they may have chosen something else.

R: "At the start can you tell them, without biasing them what's coming up? Cos at the start it's a bit like oh what have I got to do. You don't know what's coming in the whole thing."
T: "Signposting that idea that you're going to be developing an idea and speculating about possible uses of technology."

There were also some interesting suggestions from the group as to how the method could be refined.

T: "I'd say maybe after the individual stages you could get the group to pick one of the things to extend."
Y: "Yes that's a good idea."
L: "And that also solves the problem of maybe one of the tasks not quite fitting. At least one of four could be chosen."

L: "We didn't really comment on each others work or ask questions or make suggestions. So it's something you might want to encourage."

T: (about scenarios) "Tell me a task. Don't make it too technical. It feels like you're asking for something too specific and they might think but what's a scenario. Whereas if you put it in more layman's terms….Just start at a casual level."

These were all really useful comments and they were considered carefully before the second workshop.

Summary

In general the workshop process ran smoothly, and took less time than anticipated. Whilst the initial rationale behind the workshop was to identify existing technology to support collaborative processes, the scenarios generated at the end (the technology vision) seemed instead to take inspiration from the technology rather than being a direct use of it. i.e. using a combination of 'Pictionaire' and wearable devices, or table top technology and other software. This output was interesting and still relevant, but was often not yet technically feasible without development work.

In addition to this, an unexpected output was that other technologies (those not shown in the videos) were mentioned such as virtual reality, eye tracking, 'Prezi', and wearable devices. This seemed to suggest that the technology inspiration sources stimulated the participants to also consider and incorporate their existing knowledge. However, as the participants were all PhD and EngD students within the fields of HCI and Engineering, this may be as a result of them already having extensive knowledge.

The final scenarios were fairly cutting edge and bared more resemblance to the participants' 'future' visions than the original scenarios. This indicates that the 'convergent thinking' phases of the workshop were not as effective as intended. However these still yielded relevant insights into the requirements for collaborative technologies in these contexts.

Key Lessons

The following key lessons were taken forward as considerations for the future workshops:

- Allow more opportunities for collaboration
- Provide signposting early in the workshop as to what will be required of participants
- Provide more guidance regarding what is required in the scenarios
- Encourage participants to discuss current or past, rather than future, scenarios.
- Consider opportunities for further low cost 'live demos' of technology.

Changes

Based predominantly on the feedback from the workshop participants, and informal reflections, it was decided that the workshop process required further refinement. It was felt that the final stages of the workshop should be more collaborative, allowing participants to work together on a combination of ideas. The rationale behind this was that it would make the participants engage more as a group and potentially generate a more cohesive output.

In addition to this, due to the confusion with scenarios, the group were asked if they would be happy with their scenarios being shown as examples in future workshops. It was hoped that this would provide clearer signposting to future participants.

Aside from these changes, it was felt that the workshop process should remain as it was in order to see if other groups also generated outputs that were fairly forward thinking rather than technologically feasible. Whilst this output wasn't initially intended, it still yielded interesting insights and discussions.

7.5.2 Workshop 2

Due to an opportunity that arose, a second workshop was held a few days after the first and with a group of EngD students recruited by email.

Refined Process

The process used was similar as the first workshop, except that in the final phase (phase 4) the participants were asked to create a shared scenario that used technology to support all of their individual processes (as described in the individual scenarios). This decision was based on the lesson learned from the previous workshop regarding the desire for more opportunities to collaborate.

A summary of the changes is as follows:

- Providing scenario examples
- Changing phase 4 to be a group design session
- Provide clearer signposting

The workshop was carried out in the same location as the final Airbus workshop would eventually be held and provided an opportunity to establish the room set up. This was within a conference style meeting room at the CFMS Research Facility (AHRC). In this room it was possible to project the videos and slides and the table was much larger.

The participants were four EngD students all carrying out their research at Airbus.

Findings

Once again this section will provide a summary of the scenarios that were generated and how these evolved in order to evaluate the process. The first three stages were run as before but the final stage was different and will thus be discussed separately.

Figure 75 - Second Workshop Scenario Presentation

H Scenario Development

H discussed their research on controlling a workload management system on high performance computers (HPCs). During the workshop they described their first scenario as both same time/different place and same time/same place. This was because they had to keep in touch with both their industrial and academic supervisors whilst they were located at Airbus. They described working alone at a computer to collect data from HPCs. They presented demos of their work to the industrial end users in person and stayed in touch with their academic supervisors either on Skype or through short face-to-face visits.

In Scenario two H talked about a future where *"it doesn't matter if you're in a different place or not, you can access everything."* They mentioned using the cloud so that the current distributed physical HPC centres became one single virtual entity. *"How this would be done, I don't know, but I think the starting point is the cloud".* Regarding meetings H came up with an idea where people would answer lots of questions that would be stored for future reference in a 'smart recording system'. Then when people had a question these answers would be searched for the relevant answer. So people wouldn't need to have actual meetings. *"I don't know how this technology would be developed…"*

It was clear that H wanted to start thinking about how to achieve the proposed scenario so to some extent the ideas were already being turned into a solution but a solution based around 'ideal' technology.

In scenario 3 H talked about having no PC, just a table *"that's my computer".* H talked about removing the need for a number of HPC centres, and everyone working on the same thing at the same time, using cloud computing. H described this as like having *"the cloud as my research lab"* without needing to go to different centres. H also mentioned having a digital meeting with 'digital annotation'.

S Scenario Development

S discussed their work designing and implementing a new process used in aerodynamic design. In their first scenario they described how they talked to another RA in the same office regularly to get the knowledge. S also emailed their academic supervisor regularly as they were in a different office.

In scenario two they introduced the concept of telepathy. *"The ideal thing would be telepathy where you could just think of something … and your supervisors or the RA would just respond."* This links to a desire for instant replies or answers. *"You wouldn't have to email your supervisor and wait for a response… It's just instant, making things more efficient."* They also talked about being able to automatically record meetings and access data 'wherever you are'.

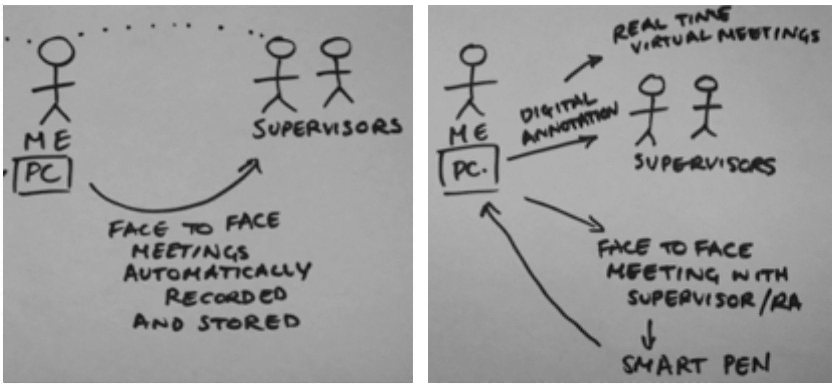

Figure 76 - S Scenario Development (Phases 2 & 3)

When talking about scenario 3, S described a system where their supervisor would have a screen in their office that questions could be sent to instantly. S also linked their idea in scenario 2 of having face-to-face meetings automatically recorded to the smartpen (“*that’s kind of been summarised in the smart pen*”). Although they pointed out that you would have to upload the notes yourself. S also mentioned the ‘Pictionaire’ table as a means of collaborating in person with other students.

J Scenario Development

J described working on an optimisation task for their thesis. In the first scenario they described their process in a number of stages that involved iterations between them talking to the customer and carrying out research. This included carrying out both low and high fidelity simulations before sharing the final results.

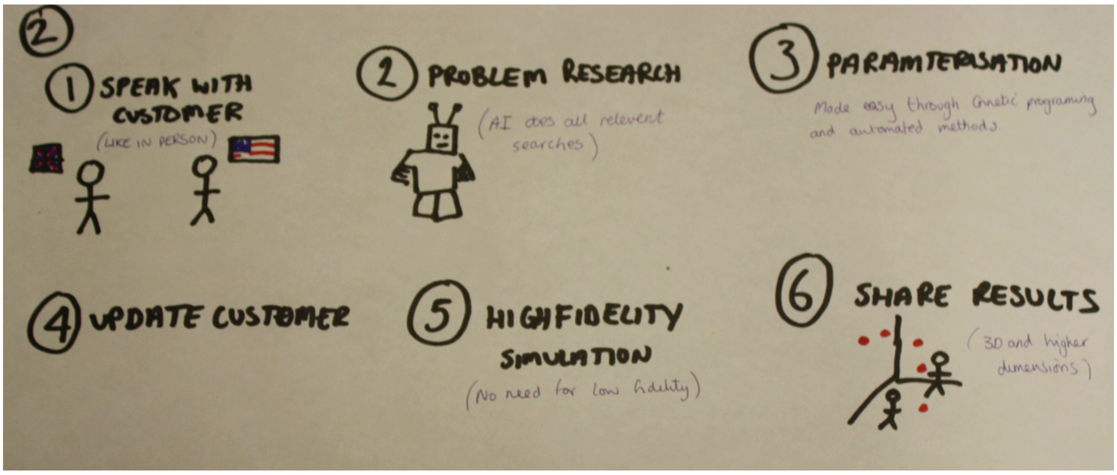

Figure 77 - J Scenario 2

Within scenario 2 J imagined a hologram for communicating with customers and the use of Artificial Intelligence for doing the research. The Lo-fi design step previously mentioned was removed, as code would not be as expensive so they could go straight to the high fidelity simulation. J also talked about a new way for sharing result. *“Results are often higher dimensions so rather than a 2D plot,…it would be cool to be in a room where you can see results projected 3D all around you”* In fact, after J had finished discussing their scenario A mentioned that there was actually a place where you could already do this.

In the third scenario J began by mentioning the technology that they had identified. *"Use all the Pictionaire, physical digital stuff. Digital annotation which I've never actually used but know it exists."* They also talked about the possibilities for technology that could help make research more efficient. *"That augmented reality thing might help, with all the object imagery".* With the third scenario J seemed to focus more on which technology could be used rather than the details of how this would be achieved.

A Scenario Development

A discussed their task of implementing technology that was originally developed by a company in Germany. A was based in the UK but needed to communicate with the team in Germany via reports and email.

A described their idea in the second scenario as being similar to S. *"Using thought, you can update a cloud floating around that can transfer things by brain".* They also mentioned the concept of 'programming in your head', controlled by thought and therefore removing the need for 'computers'. In scenario 3 A described *"having the computer back again"* but with the idea of using touchscreen on multi-devices so that you could *"flip between devices".* A also mentioned social networking sites for communication and digital annotation within remote conferences. A ended by saying that the idea was *"moving closer to that dream of a data cloud".*

It was interesting to see the way that in scenario 2 A wanted to get rid of computers as the ideal world did not need them. However they made a re-appearance in scenario 3, but with more seamless interactions between devices.

Group Scenario

In response to feedback from the first workshop a group phase was introduced. At this stage the group was asked to work together to come up with a system or series of tools that could support all the scenarios described. This replaced the individual stage of imagining the task in a different time/space context but still allowed the team to look at creating a flexible tool that could support a range of work contexts.

Figure 78 - Second Workshop Group Design Phase

This phase allowed for a greater amount of discussion, some of which is detailed below. This discussion was a useful way to understand the development of ideas and the rationale behind them.

As the paper was (by chance) oriented towards J it seemed to mean that J took the 'lead' in this discussion and used their approach of listing tasks in stages. S was notably quiet.

References to Technology

The group began by addressing tools to support communication. The ideas at this stage appeared to be a little disorganised but included a number of mentions of the technology presented in the videos and other technology.

J: The first step is always some element of communication. So ***shared files*** *is one way which is already in use.*
H: The means of sharing these files will be through….everything
…
H: instant digital file sharing
A: Like ***social networking sites*** *but instead of for social have it for sharing data.*
*H****: Integration between digital and physical****.*
…
H: Also ***digital annotation*** *would be handy as like another bit.*
A: You could have that mixed in with the likes of ***Skype*** *or whatever. You can see the people rather than writing just appearing on your work.*

At one stage A mentioned including a technology because it was 'cool'. This also occurred in the first workshop. *'How could flexible displays get integrated because they're really cool.'*

The group seemed particularly keen to identify tools that could improve their individual research efficiency as opposed to focusing just on collaborative aspects.

A: Almost like improving research efficiency or something like that.
J: I guess the more information the better right? So having a cloud based one they'd be loads of information there from all over the world.
A: Make it more interactive so you can get more hands on with your….like in virtual reality. I don't know how common that would be across all the different research areas though.
…
A: What about some sort of artificial intelligence thing that looks for commonalities between all your research so you don't have to do it all yourself. It informs the researcher of that so you might go down a whole different route that you hadn't thought of before.
…
H: Er, some sort of database of all research ever been done.
A: You'd need one hell of an algorithm though!

The talk then moved onto more 'blue sky' ideas such as a virtual room in which meetings could take place.

A: You could have like a virtual room in lots of different locations and just sort of meet up within that room and see the other people around you and try to reach out and touch them but actually they are not there.
...
H: Well I think for communication if I would like to meet my supervisor in Airbus and UK we'd come to this interactive room where you can use digital annotation. But there isn't any lab downstairs you just access the cloud where your lab is. And you use these technologies for communication.

References to Other Scenarios

It was interesting to see that group members referred to what other people had put in their scenarios before. This was something that was lacking in the first workshop and illustrates the way in which a group discussion can help combine and build on ideas.

H:... and I think the other thing would be the research element. When you (J) said artificial intelligence robots. And the kind of thing that had me would be the cloud.
...
A: What was that AI thing that you came up with. The ideal...didn't you have one?
H: I think that was (J).
J: Oh the robot.

Direction

At times there was also slight confusion about where the activity was going. The group looked to the facilitator for advice and they were asked to try and link the ideas together.

J: What's the next step. How far are we? Have we done it yet? Have we done the thing we need to do. As in what was this leading up to?
(Facilitator): How they can link together.
H: This roadmap type thing I can see is applicable to my..whatever I'm doing. I'm sure it's different to everyone else.

Group Output

Finally the group discussed the 'output' of their work. However the discussion appeared to tail off somewhat.

J: One more stage at end sharing results. So after all this there is going to be some sort of output.
H: The output could be social media or whatever.
J: The output for me would be giving back some sort of result. I guess. Yours it would be the actual (program).
A: Just communicating with all the different people to make sure everyone is satisfied with what's been produced.

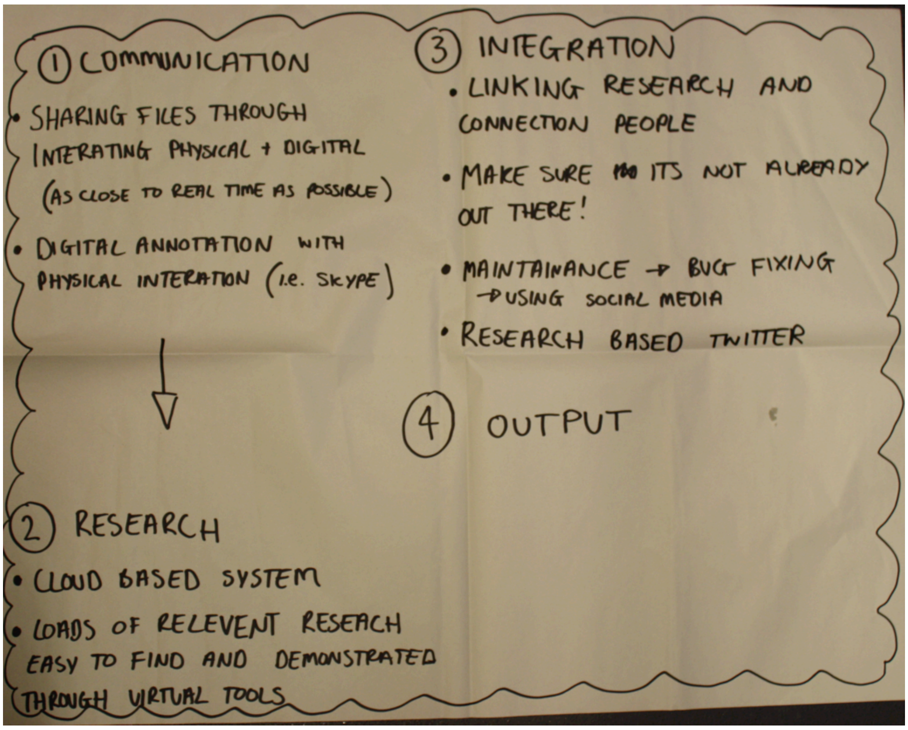

Figure 79 - Outcome from Group Session

Overall this stage seemed to draw out some interesting ideas from the group, but the actual output of the design process was unclear. As an ad-hoc response to this (and due to there being 15 minutes remaining) the group were asked to carry out one final stage. This stage involved using the ideas just described to re-draw their individual scenarios with the hope that this would encourage them to provide a more concrete output and allow the quieter members of the group to have a say. However this stage ended up being quite brief and many of the individual scenarios resembled the output from the previous individual stage.

Final Scenarios

H stuck to their idea of a desk that connects them to the main elements of their research (the research community, Airbus, and the University). This was not something that had been discussed in the group session. However they mentioned the use of a data cloud. *"My experimentation would be in the data cloud and pretty much we're just connecting via digital annotation for meetings, social media for posing questions".*

S admitted that their idea was *"pretty much the same*". *"It's me and this big data cloud and anyone can access it"*. The technologies mentioned included digital annotation for meetings, and real time updates via social media. However S did include the 'research database' that would *"tell you if you were doing the same kind of research as everyone else."* It is worth noting that S did mention worries relating to whether you would want access to too much information.

J also mentioned the concept of technology that could help you find out what's been done before as well as the cloud. *"I just stuck all mine in one big cloud. Just the master cloud or something."* J stated that the optimisation process itself hadn't really changed but that *"the major step that has changed is this updating which is* *just constant updates all the time".* They also mentioned live sharing of their simulations in the cloud.

A kept their description brief. *"I've got all different parties involved, all in their virtual spaces ready for a meeting using digital annotation. Sharing through one big data cloud. Integrating digital and physical so if I have some notes or whatever just send it across to the data cloud to be accessed by any of them."* There was a very slight refinement from their idea in scenario three.

Overall this final stage didn't appear to add much to either the third individual scenarios or the group scenario (which was not particularly concrete). It may be that extending the group stage into more of a discussion session may yield more interesting results, although possibly at the expense of concrete design ideas.

Workshop Summary

Within this workshop the scenarios appeared to focus more on the research process as a whole rather than a particular task (as seen in the first workshop). Whilst this was interesting, it did appear to lead to less concrete ideas of how these could be changed. Instead of looking at technology to support tasks, it was more aimed at concepts such as 'communication' or 'research'.

The group phase was interesting as it was possible to hear and see the thinking and design process behind the scenarios more clearly. It also allowed the group to identify similarities between their work. The initial rationale behind this phase was to come up with a design that was flexible enough to support a variety of different tasks, however on this level it was not hugely successful as the group identified a range of technologies and ideas rather than a single piece of technology. Yet it was still valuable for identifying themes and ideas and the discussion could feasibly be analysed in depth to identify further requirements.

Overall this workshop produced less concrete ideas than the first workshop, and seemed to move away from tasks, to higher-level research processes. Additionally the outputs were once again ideas for technology that were still a little ahead of the current state of the art.

Key Lessons

- Find ways to avoid domination from certain group members
- Consider removing the final individual design stage as it added very little additional value
- Look for ways to encourage the development of concrete design ideas

Changes

It was felt that the process (particularly towards the end) was still in need of refinement and the opportunity arose to carry out another workshop two days later. This opportunity arose as the result of participants discussing the workshop at an event and others volunteering to take part. There was very little time to reflect in depth on the method or develop alternative processes and thus it was decided to carry out the third workshop in a similar fashion. However, it was decided that as the final individual stage yielded little extra information, the group design stage would be allowed to last longer in order to further develop the discussions.

7.5.3 Workshop 3

This workshop once again featured EngD students working at Airbus (P, H, A, and C). It was held in a 'breakout area' of the AHRC building that was not occupied. Due to a lack of projectors, the slides and videos were displayed on a laptop. The table setup was not ideal as two round tables needed to be placed next to each other (see Figure 80).

Figure 80 - Workshop 3

The following section will once again describe the way in which the scenarios developed, to illustrate the evolution of the design outputs.

P Scenario Development

P described their initial scenario as a model of communication within their research and highlighted the means through which this was achieved (a combination of email, face-to-face communication, and teleconferencing). As their industrial supervisor was in Germany, communication with them was almost always remote. P also highlighted their data storage so that they could work on documents whilst in different places (EngD students often have to work across a number of locations).

In their second scenario P once again listed all the key people and described an idea where everyone would be *"wearing some sort of apparatus that interfaces directly with our brain and transports us effectively in our minds to what is essentially a small version of the matrix… A completely virtual office area such that we can communicate face-to-face with people in a fully immersive 3D environment."* P ended by saying that *"what's even better is they wouldn't need to leave the house to go to work."*

In the final scenario P stated that "*mine is halfway to the previous one where you have an entirely virtual world. This is just a room where there is one full wall that is a screen*". P liked the idea of being able to merge with another room. *"A room where you can walk in and out like a real physical room. An expensive room!"*

H Scenario Development

H focused their scenario on how they communicated with their academic supervisor through face-to-face means and email. In the second scenario H described how they *"…didn't really come up with anything cos I'm not very imaginative…I still think the most effective way of discussing things is through face-to-face meetings. There's not anything you could come up with that would improve this…".* When asked about how email would work H replied by saying *"What's wrong with email right…I just can't think of any way of improving it. I just can't think outside the box or something".* It was really interesting to see someone admitting that they couldn't see potential improvements.

When discussing scenario 3, H kept the description fairly short. "*I didn't have many ideas of how that would be very useful but I thought the pen would be handy just to record whatever notes that you're making". "The data visualisation looks really cool but overall I think with all that stuff it's just very gimmicky and not that practical. But that's just what I generally do, be negative about stuff."*

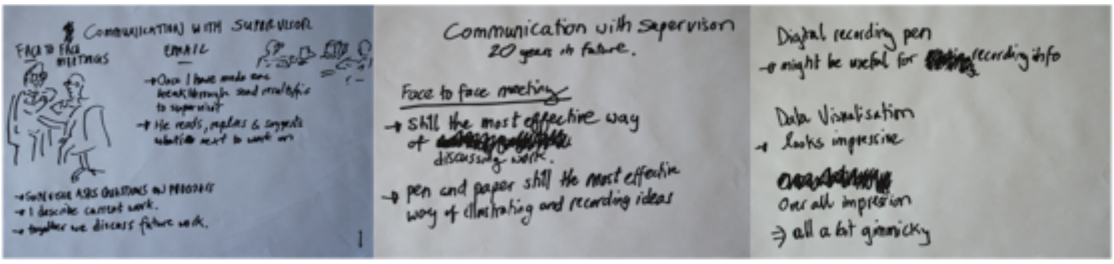

Figure 81 - Scenarios by H

These comments by H were in stark contrast to the other members of the group, however it was very interesting to see such a different perspective. It was also interesting to see that despite seeing no room for improvement initially, H was able to identify two potentially useful technology concepts in their final individual scenario.

C Scenario Development

C described a scenario about how they decided on a research topic. C used to meet every week with their supervisor for a review before asking people interested in the topic for ideas. This included meeting the design team at Airbus. In scenario 2, C revisited the concept of identifying a research topic and the need to understand how things currently work, particularly the flow of information. C proposed a wall based interface *"with a section representing the flow of information"*. They also mentioned that it would be good to have a *"high tech table with fully portable data"* that would allow video calls and the ability *"to plot quickly in meetings"*.

C's final scenario was very brief. They liked the idea of a digital annotation wall to share information - *"To see updates on [wing] geometries".* They also highlighted Pictionaire as being useful although they did not go into details about how.

A Scenario Development

A provided a really in depth initial scenario describing the process and tools used when writing a joint paper with their supervisor. It included face-to-face meetings using whiteboards, paper management tools (Mendeley), and email. A mentioned that whiteboards *"are useful because we write lots of stuff on the board at the same time same place. We write on it and come back to it later (dif time same place)".* When discussing remote meetings on Skype A talked about using a webcam for showing handwritten notes *"as it's easier to do it on paper".* When discussing the actual writing process A said that *"this is where tool support is pretty annoying"* as they use Word to track changes before converting it to Latex at the end.

As A admits, their second scenario is more like a list of *"cool techs that would help"*. This was quite exhaustive and included some the following ideas:

- *"I think all rooms are going to have like wall sized TVs…It looks like a sheet of glass like in the video. It's cool and I think it's coming".*
- *"Something that would be SO awesome would be an automatic detection of 'now is a convenient time to meet, you're all free, you're all in a good mood to meet, reading your biometrics and your plans and that kind of thing…now go and have a meeting..."*
- "*Another simple one, diagraming on a wall and automatically capturing it to a sheet of paper. So if you do write on the glass, it's always scanning it."*

A seemed very enthused by the ideas. It is worth noting that many of these were grounded in A's understanding of existing technology and its capabilities. In the third scenario A's initial list of 'cool techs' formed into more specific ideas. For simultaneous editing they described how *"you could have a table or a wall or some kind of connected surface where you have multi-touch, where you have like digital and physical boundaries that are quite thin."* A also picked up on the idea of using the phone to carry data and transport it to a surface (as seen in the videos). *"You don't need to pick up a whole pack of files, you just pick up your phone (and put it on the table)."*

Group Design

The group design phase was introduced in the same manner as the previous workshop. In this stage the group was asked to come up with a system that could support all of their scenarios. They were provided with paper that was stuck on the wall so as not to orient it to a subset of the group (addressing the lessons learned in Workshop 2). However, A generally led this session, with input from P and C. H did not contribute to this stage but was present in the room. A full transcription of this conversation can be found in Appendix C.

The design idea emerged almost instantly through a conversation led by A and was similar to their final individual scenario.

A: To be fair, I think some combination of that and that [points to scenarios]. So where you have a wall with a table on it and the table is one of those funky tables where you can physically move stuff.
P: A surface that you can touch?
A: So there's a vertical surface through which you can see the other people so you're getting the physical feedback from the other side and then there's a sort of 'manipulable' virtual surface coming out the wall. So rather than just a flat table it's actually one of these funky surface things and you can flick things to people.
(drawing)….This is basically a big TV wall and it has multi-touch tables, which looks circular but is only half circular…

Evolving Ideas

Whilst A and P seemed to have come up with an idea that worked for them, C was not sure that this design would meet their needs. As a result the design evolved through further discussions.

C: Not in my case because I dunno what's happening in the tools, in the design team, this is not that usable.
A: But you could have it on there and then you could drag it up on the wall. There are like panels. So it's like a glass thing that you can stick onto the screen like a presentation.
…
C: Because what you are talking about is a meeting. … It might not be a meeting. I'm walking, I'm having coffee, I see what's going on there. Ok? This could be really useful.
A: You see rather than having this normal meeting wall, have it in more of a social area.
C: Yes exactly. Either it can be used for a meeting, but having a social area you can see what's happening from …
A: So a flexible wall where you can put up feeds or whatever.

Facilitator Input

Towards the end of the session it was possible (as the workshop facilitator) to ask some questions to challenge the design. This was carried out on the spur of the moment, but the aim was to try and get the group to ground their ideas more as they were still fairly futuristic.

In one instance the group were asked if they could use the system in 'all parts of the time/space matrix'. In response they modified the design slightly. Additionally they were asked if this could be accessed remotely by someone without a physical room like this.

A: Same time different place, that's where the back wall comes in.
P: And then the different types, like C was talking about, being able to access, basically a very elaborate noticeboard of what information is relevant to you about the broader context.
…
F: What about mobile use? If you couldn't be there.

A: If the artefacts are digital, on the table, on the wall, you want them in a different form so that you can see them on a small screen. But if they're digital artefacts you can kind of transform them to how you want them to be.

The session ended with an interesting discussion on the fact that two of the students were at universities that already had similar rooms or video walls that were not utilised (this was initiated by them). They seemed to come to the conclusion that the system needed to be cheap enough to make, and it would need a critical mass of use.

Workshop Summary

This workshop again differed quite considerably from the previous two. Initially there were a mix of scenarios presented, some being quite specific tasks, and others being a general overview of the research process. However, as the workshop progressed, the ideas became more concrete, converging eventually on a single, quite specific design idea. It is not clear why this happened in this workshop, but not in the previous one, but it may simply be down to the dynamics of the group.

The scenario progression of H is of particular interest, as they could not envision anything better than their original scenario initially. H then identified a couple of items of technology as being potentially useful but dismissed most of the technology as being too gimmicky. H identified this 'negativity' as a personality trait, but it does show that this method may not be suited to everyone. However, the points they made were very valid, and their contribution was still interesting and relevant.

Key Lessons

- Encourage participants to be honest
- The group design stage can be further facilitated as necessary
- Be aware of group dynamics and remain flexible to suit the particular needs of the group

Changes

Overall this workshop felt more successful than the previous workshop as the final group session flowed more naturally and produced a more concrete output. As a result of this few major changes were deemed necessary. However, in response to the different group dynamics across the three workshops, it was decided that in future the final group stage of the workshop should be left flexible, with the facilitator deciding which steps are most appropriate.

7.5.4 Pilot Workshops - Summary

This section has described the process by which the workshop process was refined before the final workshop was run at Airbus. It can be seen how the final stages ended up being different in each workshop and the decision was made to keep this flexible. In addition to this, small refinements such as better signposting of upcoming activities, and showing scenario examples, were made.

Although the workshop process could have been further refined after the initial three workshops (such as considering ways to ground the final scenario ideas in more realistic technology), time constraints meant that it was necessary to progress to the final workshop.

The next section will detail the design ideas and scenarios that emerged during the final workshop, before providing an evaluation of the method as a whole.

7.6 Final Workshop

This section will discuss the final workshop carried out during this phase of research. This was carried out with Airbus employees and was no longer a trial of the workshop method, but was instead focused on providing a design output.

7.6.1 Participants

Gathering participants for this workshop ended up being a very challenging process. This in part stemmed from the fact that it was not possible for employees from SDC to attend (for reasons that could not be controlled). This meant that gaining access to software developers was problematic. However luckily an employee at Airbus (C) was currently working there as part of a placement program. Therefore this participant was able to represent the software development perspective.

A key user from Airbus (R) who had been observed during earlier ethnographic work was approached and was very happy to participate. It is worth nothing that although R was recruited as a key user, they referred to their role as 'Business Process Lead' (BPL). Earlier work witnessed this role being fulfilled by members of the Methods and Tools team, but it can also be members of the aerodynamic design team. The key point is that R's role was to advise the design from the perspective of the 'business processes'.

The final participant was a current member of the AHRC (A) but prior to this had worked in software development (advising from a business perspective) and thus represented the Methods and Tools team.

The selection of participants was not ideal and it would have been preferable to have a fourth member. However, asking for nearly three hours of people's time (two hours for the workshop plus travelling time) turned out to be a bigger barrier than anticipated.

7.6.2 Resources

As with the pilot workshops, A3 paper and coloured pens were provided. All technology cards were used, along with the addition of the concept cards.

7.6.3 Process

The initial aim was to run the workshop in the same way as Workshop 3, but with further flexibility towards the end, during the group design phase. However, in reality during the third phase (the 'technology inspired' scenarios) the participants started an impromptu discussion about desired features of technology, and thus the 'technology scenarios' were not formally developed. This again highlights the need for flexibility with the process.

It should also be noted that an analysis phase was used within this workshop in order to identify further requirements and identify potential technology.

7.6.4 Analysis

The workshop was analysed on two levels. Firstly to establish the design ideas to take forwards and secondly the workshop was included in a reflection on the workshop method, which will be presented at the end of this chapter.

7.6.5 Design Analysis

Having completed the workshop, the design outputs were not as concrete as initially intended, but this was not surprising as the pilot workshops also had similarly high-level outputs. Rather than identifying particular technology, the workshop instead involved discussions of desirable features of technology within the software development context at Airbus.

Subsequently it was realised that the scenarios and discussion would need to be analysed more formally in order to draw out the design ideas and any further requirements. Through this process it was possible to identify key themes, which in turn could be matched to the existing technology presented at the workshop. This analysis became a key part of the design process and should be acknowledged as a deviation from the original vision for the workshop.

In order to carry out this analysis, the workshop audio was transcribed in full before being coded and grouped to identify key themes. The key themes can be seen in Table 7 and will be described in more detail later.

Table 7 - Coding Themes

Themes	Occurrences
Requirements	16
Traceability and Documentation	14
Automatic Recording	12
Barriers to Use	12
User and Developer Roles	11
References to Airbus Systems	10
Stakeholders and Development Teams	9
Single Interface/Repository	4

The following section provides a high level reflection on the workshop themes and discussions around the scenarios.

Initial Reflections

This workshop diverged from the process quite significantly towards the end. This was not discouraged, as the discussions were useful and collaborative. Discussions included how the technology could help the participants (above and beyond their scenarios) as well as the fact that some of this technology was already available to them, but not used. Reasons for this were then discussed. These reflections on barriers to technology use yielded interesting considerations for rolling out any technology in this setting.

In addition to this, the design ideas discussed seemed to be more realistic, and linked more closely to the technology. This may be due to the fact that it was taken more seriously by the participants, as in previous studies the participants were aware that it was a pilot study.

Scenarios

Figure 82 shows the initial scenario drawn by the 'Key User/BPL' (R). The first realisation with this scenario was the way in which it very much represented the process as described during the ethnographic work. Here the BPL is representing the 'customers' (the engineers) and their job is to liaise with the project team by providing requirements (from their domain knowledge). They will in turn return with the constraints. This is an iterative cycle that continues into the development process, which R simplified.

R in fact used two pages of paper to represent their scenario and went on to explicitly list their frustrations, including the fact that "project work seems to be heavier than the value added to that part of the project".

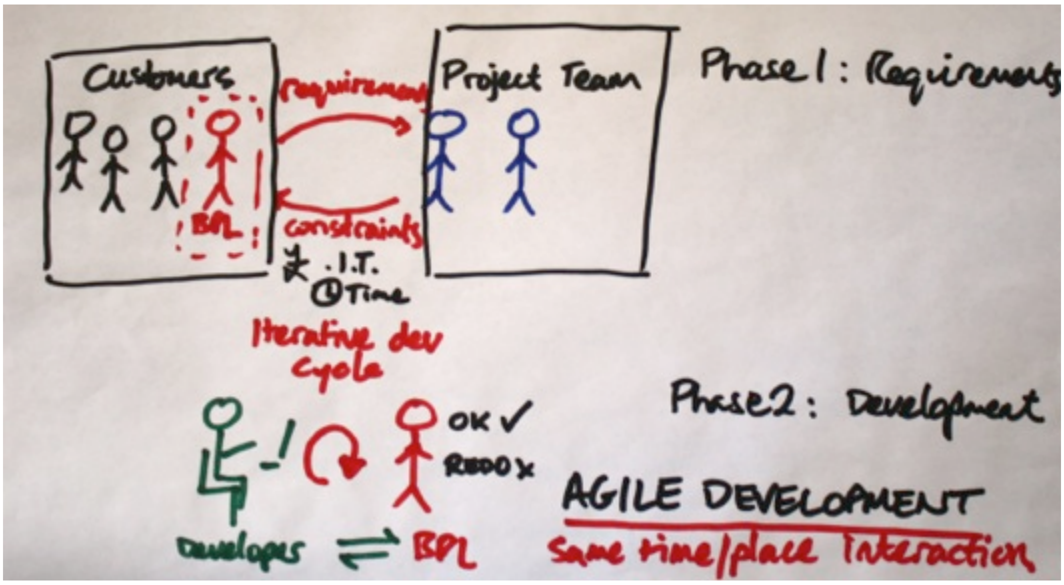

Figure 82 - Key User Scenario 1

R chose to talk about a project where they represented the users and the ways in which they used agile development. This included sitting down with a developer face-to-face. R picked up on issues with having to produce documentation that was more heavyweight than necessary.

A talked about the development of a wiki to be used within the aerodynamics group for knowledge management. In the scenario they mostly highlighted issues that the tool was trying to solve, rather than issues with the development process itself (this will be discussed later).

C talked about the development of a new tool and the ways in which the teams meet online with customers (users) to overview new system features.

User/Developer Roles

Much of the discussion from S2 onwards focused on the roles of the users and 'programmers'. It became clear that R as a user wanted to be able to create tools themself, or work closely with the developer to develop mock-ups on the fly. This progressed into talks of the ability to program systems directly through the use of natural interfaces (perhaps sketches that could automatically become workable prototypes). This would save time, and allow for fast feedback iterations.

The role of the user seemed to be closer to that of the developer and A in fact stated that the most successful systems at Airbus had been developed by users.

Within S2 there seemed a fairly large focus (from A and R at least) on the fact that technology should be made that allows users to develop their own tools. This discussion progressed after the technology videos had been shown, with both R and A keen to have a system that would allow them to play with ideas using natural 'language' or visual programming. C also got involved in this discussion.

A: "It would be ideal if you could draw this and it would turn into reality without the coding behind it."
R: "That is what I was trying to get at with my second slide [scenario]. I was trying to express something and how I wanted it to look and [they] would make it work and I could test it and see if I like it…You get so much more value because you've explored everything you can."
…..
C: "So like a tool that would make your language into programming code or something."
A: "But without the programmer if you want. Because everyone would be able to code by just using normal language"
….
R: "it would be ideal if you could draw this and it would turn into reality without the coding behind it."

This desire is not new, and many languages have been developed to try and make coding more accessible. Visual languages such as LabView have tried this yet still require a conceptual knowledge of programming. Developing something like this would be quite challenging and not something that this research project could tackle directly (due to time constraints). It seems that this desire stems from frustrations with working with developers, and the feeling that they could 'do a better job themselves'. Thus attempts could be made to tackle this in a less direct fashion, by looking at tools to support better, and more efficient communication of ideas, and provision of more instant feedback on these.

Collaboration/Software Development Teams

Further discussions about 'problems' look at collaboration between software teams.

R: *"Part of the issue with the subcontractors for us is that they're not collaborative. We design requirements, we give them requirements. They go away and come back with some complete software and that may or may not meet our requirements because we may not have expressed our requirements properly and the thing that* *worked better was when we sat together and looked at the software at the same time."*

The theme of requirements was actually a recurring topic.

Requirements

There seemed to be a consensus amongst the group that certain requirements can be hard to express in writing, which could lead to misunderstandings and wasted development time. This often linked to the 'look and feel' of the systems. They felt that there was some potential for the technology to assist with this.

"Digital annotation (looks through piles of cards)…something in there has got the ability that allows someone to sort of draw something that would show what you have in mind…and you say 'this is what I want. I don't care how, what the technology behind it would be, but this is what I would like."

Documentation

In addition to discussions on requirements, the participants also expressed frustrations about having to produce documentation. This especially linked to having to create formal documentation to satisfy management that appeared to provide little benefit. This strongly reflects issues discussed previously about the need to create 'heavyweight' documentation to satisfy official procedures.

R: "the small projects milestone process where every single thing that we did had to be documented to a specific standard and a very…rigid specific manner with people who were so unlinked to the specifics of the project but had direct control of the project because they were money people and they had all the budget. So we had to continuously feedback to the project people and report on what we were doing in a very rigid way, which felt like a heavier task than the value that I was adding as a business project leader in terms of the requirements of the software itself."

These frustrations were expressed early on, and later design ideas reflected a desire to be able to create such documents automatically.

Automatic

C talked about using automated recording to make better use of time. Something that could create minutes automatically so that you don't have to spend *"15, 30 minutes every day every week just writing the minutes".*

It came across that there was a strong desire for tools that could help 'automate' the process of recording decisions.

"The key thing is that it captures all the requirements as you're working and that can be formalised automatically by some clever system and…all the documentation and everything that you need to do to satisfy the money people can be generated in a way that is suitable for the project"

"there's lots of verbal turned into written, having voice recognition so that you can actually have an interview and automatically it's all correct, it's all fine, it's been recorded".

"what you (in the design features presentation) were talking about capturing decisions. That would be a really useful took in an ad-hoc way. Something like an app on your phone that could record decisions and categorise them."

"some kind of technology that would help you capture knowledge in real time…and it would process it and put it in a document…or you know, it would send it directly to the money people to speed things up and make it easier for you."

This was one of the overwhelming themes of the workshop and it seemed to link to both saving time and more accurately recording decisions and requirements.

Barriers to System Uptake

The feel was that the videos made the participants frustrated that these tools existed, yet Airbus wasn't using them. This wasn't necessarily to do with a lack of awareness of them, but rather that barriers to their use or introduction existed. Some of this related to reluctance to change and buy-in from management or users. One participant linked this to the potentially dated attitudes of staff members (from a different generation).

The group picked up on the issue of people trying to use tools in the same way as old tools and even looked to themselves as being somehow responsible for this. However they also discussed ideas for overcoming this problem.

(in reference to a colleague) *"[they're] so resistive to use it that when [they do] try it and use it [they] use it in exactly the same way as the old tool which means that [they] find it so frustrating because it doesn't do what [they] want it to."*

A: *"I'm a bit disappointed in myself. I can't find a reason why….When I saw them I was like 'this is really cool' but then I never used it and I don't know why".*

A: *"I wonder if something that is disruptive, disruptive as in completely new, would help because if you're bringing something that has got a little incremental benefit there will still be much resistance that is like 'why do we have to change everything for that'….but I wonder if it was completely new,…maybe it would be easier."*

7.7 Workshop Design Outputs

Whilst many of the desires and issues related to methods for automatically programming systems without the need for (or a reduced need for) a developer, this was not something that this research could tackle directly, due to the sheer scale of the problem space. However, ways of improving the communication and recording of requirements was something that could be addressed. In fact, the general wish for ways to automatically record ideas, discussions, and decisions was something that existing technology could help with.

7.7.1 Additional Analysis

Whilst the participants didn't come up with explicit ideas for the ways in which the technology could support new processes (as was the initial intention), their discussions and scenarios helped highlight the key features that they needed. It was therefore felt that the workshop still had value. The focus on specific technology meant that they were able to highlight useful features of these, whilst also addressing barriers to uptake.

It was determined that the workshop audio should be transcribed and studied in detail. The discussions within the workshop were analysed and coded to identify the key themes within it. Through this it was possible to begin to identify technology that could satisfy these (from those shown in the workshop). A prominent desire emerged for technology that records decisions automatically and helps create documentation more efficiently.

The following sections will outline the technology that was identified through this analysis as well as further requirements.

7.7.2 Further Requirements

As well as identifying potential technology, the workshop process also allowed for requirements to be further refined. Additions to the requirements are summarised as follows:

- Make capture of decisions as simple as possible (perhaps automatically)
- Reduce barriers to system uptake
- Support the ability to create formal documentation automatically or with as little effort as possible.
- Support the creation of documentation for management purposes.
- Allow requirements to be represented and communicated visually.

7.7.3 Potential Technology

Once the analysis was complete it was necessary to identify technology to take forward for a small-scale deployment. Whilst it had been anticipated initially that these would be selected directly by the workshop participants, this was not the case due to the discursive nature of the final workshop.

Two options were available at this point in time. Either technology could be selected from the 'technology inspiration' sources, or an entirely new technology could be found that could meet the requirements. After carrying out the analysis of the final workshop, two of the original 'inspiration' technologies stood out. This was not unexpected as many of the technologies were included due to the way in which they potentially met the requirements.

These technologies were the Livescribe smartpen and tablet computing. The reason these stood out is that they are both portable, lightweight, and flexible, and will allow audio to be recorded, along with drawings and text during meetings. Their connectivity also allows for the documents created to be shared.

Whilst these technologies could feasibly have been identified previously based on the output from the ethnographic work (and were included in the video material for this reason), the workshop highlighted more clearly the type of features that the stakeholders wanted (automatic recording being a recurring theme). It was through the workshop analysis that these two particular technologies became clear candidates for further investigation.

The next chapter will discuss the evaluation of these tools in context to see if was possible to identify a potential candidate for more formal introduction into the workplace. However, firstly the workshop method as a whole will be reflected on in the next section.

7.8 Reflections on Workshop Method

This section provides an evaluation of the workshop process, mainly focusing on the last workshop as the success of the first three workshops has been reflected on in the previous section. However, some analysis of these workshops will be included in order to reflect on the method as a whole.

The last section looked at the 'design' output of the Airbus workshop, whilst this will focus on the methods used on a more general level. This section will look at the design process in the workshops to see how people referenced ideas and technologies from the videos and each other as well as how the resources were used.

7.8.1 Findings

During the final workshop there were 10 references to Airbus technology, which highlighted the ways in which reflections on existing systems became a core part of the workshop. In addition to this, 10 references were made to the content of the videos and the particular technologies within them. Finally, there were 12 mentions of barriers to technology use (as has already been discussed).

Difficulties

Some participants struggled when asked to visualise their process in the future. Many participants openly stated that it was a hard task and in fact one participant in the third workshop stated that they would not change anything, as what they currently did was fine (however they later suggested that smartpens could be useful).

In the final workshop both R and A mentioned difficulties with creating scenario two (blue sky). A in particular mentioned finding it *"really difficult to not shift from the process to the tool"* which referred to them finding it difficult to think about a new process, rather than features of a tool.

Techniques for making this process less intimidating and more accessible should therefore be considered. These should aim to assist the participants with the scenario creation, and give them a better understanding of how this fits into the workshop process as a whole. Processes may need to be investigated that can help get participants into a more 'divergent' mind-set. For example, creative thinking exercises could be included (much like those used by Marois, Viallet, Poirier, and Chauvin (2010)).

The concept and creation of the scenarios also caused some confusion. In the first workshop, as has been previously discussed, the group were anxious about the exact output that was expected. This seemed to be somewhat solved by providing examples in future workshops. However, the work processes described in the scenarios also caused confusion.

In the Airbus workshop the first scenarios provided some confusion. A talked about the issues that their new software was going to address, as opposed to the issues in the development of the software. However, this was still of interest and referenced areas previously covered in ethnographic work.

However, this confusion could have been avoided had a clearer idea of the purpose of the scenarios been provided. Additionally clearer signposting would have been useful.

Blue Sky Ideas

R described one of their new ideas as 'silly' but it was actually the type of vision that was desired. What they had done was to take a positive point from their initial 'scenario 1' process and extended it.

"This collaborative environment where the customer and developer are working together is really good. But what if you took it to the level where you could have an environment where you could develop the software on the fly…trying things as you were developing and you could test it and see the results instantaneously"

This may have been something that R deemed to be currently unfeasible, but it highlights their frustrations with the current system. Thus the 'future' visions often served as a way to probe the insufficiencies of the existing processes.

External References

At the Airbus workshop R referenced two visions in the Matrix, combining their vision with what they had seen in the film. This indicates that aside from the visions of the future presented, R also used those that were already in their frame of reference. In fact in the first workshop, T also mentioned the Matrix.

R: "I'm thinking about when I watch the matrix and watching those people control the gate to the city in the middle of the world, I can't remember what it's called, Zion?, and they're sort of moving things around with their hands and I just have this idea in my head that you could have a software environment like that that doesn't mean necessarily have to mean you're sat next to someone, it could be virtual, they're somewhere else but it's 'same time'."

R also interestingly made a reference to the time/space matrix in this quote (which was shown at the beginning of the workshop). This appeared to provide a shared reference in which to describe how their system would be used.

At the first workshop one of the attendees mentioned other technology that they had seen somewhere that allowed people to project onto surfaces such as their hands (this is Sixth Sense) and subsequently that technology was added to the set of technologies in later videos.

It was interesting that the videos prompted ideas aside from those being shown and indicates that the triggers inspired other interesting thoughts.

References to Existing Tools

During the final workshop there were a number of references to tools already used at Airbus, either as examples of things that worked, or as examples of things that did not.

R: (in reference to new existing system) *"It's good. It means that all the guys that need to do wing design, wherever you're sat in the company, can just connect and do it."*

The discussions around this were interesting, and also led to interesting discussions on issues such as barriers to technology use. This is something that could be encouraged if the method was to be used again.

Workshop Facilitation

During the discussions it became possible to probe issues and ideas further and to ask questions to clarify things that had been observed:

Facilitator: *"Just a quick question. I found from observing things that it wasn't always the look and feel of tools that was a problem as much as what was going on behind the scenes so…it wasn't the interface that was a problem but it was the processes it was following and how it matched your workflows."*

This stemmed from a number of references to how systems looked rather than 'what they did'. This was briefly answered (it is other things too beyond the look and feel) but the team quickly moved on to discussing something else.

In general this facilitator input was infrequent to avoid biasing the stakeholders, and the discussions flowed freely without any intervention.

Workshop Process

In general the future and technology inspired scenarios often had the most similarities, for example sharing data telepathically became sharing all data in the cloud (and this being delivered as and when it's needed). Sending emails, and teleporting to conferences (rather than flying) was replaced by Virtual Reality headsets. Whilst this indicates the process was successful in getting people to step away from existing constraints, it also meant that the final scenarios were often still very creative and not based solely on the existing technologies shown to participants.

In the industry workshop the participants began a spontaneous group discussion about the technology seen in the technology videos. This included discussions on how it could help them (above and beyond their scenarios) as well as the fact that some of this technology was already available to them, but not used. Reasons for this were then discussed. These reflections on barriers to technology use yielded interesting considerations for rolling out any technology in this setting.

During this discussion it became clear that it was very interesting and in fact a vital consideration. Thus the participants were encouraged to continue to work together on their ideas. As the discussion drew to a close, they were then asked if they would like to use the last 20 minutes of the workshop to draw another scenario (or work together to discuss a design). R responded that yes they would like to think about a design as "I've got a few ideas".

Design Ideas

When presenting the technology inspired scenarios the participants often referred to technologies specifically by name. However in some cases these were also combined and developed further to produce more advanced technology. For example, on more than one occasion the students expressed the desire to have a video wall connected to a touch surface where digital artefacts could be shared.

This design convergence across workshops was also of interest as it may indicate that the technology inspiration sources provided too strong a bias (as Marois, Viallet, Poirier, and Chauvin, (2010) found with interactive illustrations) or that this was genuinely something that would be desirable.

In the student workshops the final design ideas were often technologically advanced. Whilst components of this technology are available in isolation, the costs to combining the technology may be high. This isn't a negative output but further sessions would be needed to refine the design ideas to a more realistic level if this was desired.

In the industry workshop the final discussion related to the properties that would be desirable in technology i.e. a portable tool or a single consistent interface to a number of systems. This move towards design properties rather than an actual design was useful but wasn't the intended output.

Group Design

The group phase of the workshops were less successful than anticipated in terms of generating a combined design idea. In the second workshop the group struggled to come up with a clear design idea, whilst in the third the group had problems satisfying all their needs.

However, the discussions in this phase actually brought an added value to the session when analysed in more detail. Future refinements might replace this final session with a discussion of key themes or requirements, perhaps grouping design ideas together. However, it would be useful to match this to the existing technologies to provide a more concrete output.

Resources

The technology cards were regularly referred to by the participants during the workshops. They would pick them up and point to them when explaining their scenarios and they were also seen to search through the cards when working individually. However, the QR code linked videos were not used by the teams, aside from getting them to work initially. In fact they became more of a live technology demo, which is something that could be made use of in future sessions.

Figure 83 - Card Use in Workshop

The design concept cards used in the final workshop at Airbus were only referred to directly once, yet the designs discussed tended to fit the desired properties well. For example the need for a tool to work in “a number of contexts” was realised as a tool that was portable and so it could be inferred that the participants took on board the concepts. This is an area that would benefit from further studies of the workshop method.

Validation of Earlier Findings

During the design analysis of the workshop audio and scenarios, it became clear that the key challenges highlighted in earlier work were a common topic within the discussions.

“So these are all problems we are trying to solve with this tool. One was there are bits of paper in people’s drawers and we don’t know where they are and some people have access and somebody working by themselves on their computer not having access to experts and other people learning key things around a coffee table during a break but again it wasn’t shared because it was just one person, a lucky chance.”

This alludes to the challenges arising from ad-hoc discussions not being recorded and information stored and/or shared for traceability purposes. In this example, they had tackled these issues by creating a wiki.

R: “the small projects milestone process where every single thing that we did had to be documented to a specific standard and a very…rigid specific manner with people who were so unlinked to the specifics of the project but had direct control of the project because they were money people and they had all the budget. So we had to *continuously feedback to the project people and report on what we were doing in a very rigid way, which felt like a heavier task than the value that I was adding as a business project leader in terms of the requirements of the software itself."*

This was mentioned in the analysis of the workshop, but provides a key example of the way in which the workshop served to validate earlier findings.

7.9 Conclusions

This section has described the development of a design workshop that aimed to involve stakeholders in identifying existing technology that may meet the requirements identified in the earlier ethnographic studies. Whilst refining and evaluating the success of the workshop method, this work also resulted in design ideas and further requirements to take forward.

It is important to note that this chapter has provided a high level reflection on the workshop method and the design outputs. It was not feasible at this stage to begin to deduce the reliability or validity of the workshop method due to the limited number of workshops carried out, and the variability in the methods used. Instead this chapter has set out to refine the method for the practical purpose of generating design ideas (and further requirements) to be investigated through technology deployments.

The workshop method could be explored and evaluated further in future research, however due to the industrial context of this research it was not practical to do so. The following section suggests how the method could be improved based on the reflections in this chapter.

7.9.1 Recommendations for Future Workshops

Through revisiting the literature after the workshops it was possible to see where further stages could be added to the workshop. Resnick (2007) talks of the creative power of iteration and the kindergarten approach of imagine, create, play, share, and reflect. Having seen the benefits of an impromptu group reflection such a phase could be added after each presentation of scenarios. A process of group reflection may generate some interesting ideas and make the workshop more collaborative.

Additionally it might be useful to provide more information, and possibly even some activities prior to the workshop. The participants came to the workshop with very little idea of what was ahead and sometimes they struggled to generate ideas initially. With better framing of the workshop and some reflection time in advance, the early stages of the workshop may flow better.

Finally, with the outputs being quite mixed across workshops it would be useful to develop ways to make this more concrete (and technologically feasible). Follow up activities or a future plan of action (as was used in the Future Workshops (Kensing, Halskov, & Madsen, 1991)) may make the task seem more 'real' and thus the participants may focus more clearly on the output.

Chapter 8

Tool Evaluation

8.1 Introduction

Having carried out the design workshop at Airbus and the analysis of the data generated from it, the next step was to evaluate the use of the two selected technologies in context with stakeholders in systems development.

The aim of this phase of the design process was to evaluate the results of the design workshops, establish how well the identified tools met the requirements, and explore whether they could effectively and satisfactorily support the work of the stakeholders.

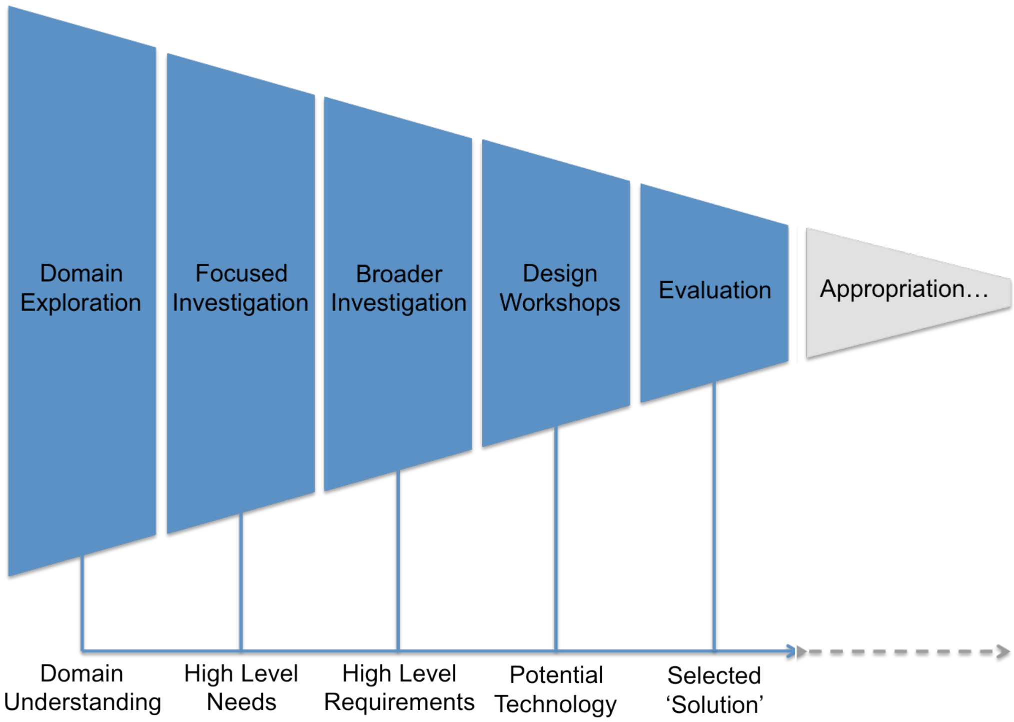

Figure 84 - Stage of Research Process

8.2 The Technologies

This section will provide a more comprehensive overview of the two technologies selected as potential solutions to the requirements identified within the previous ethnographic studies and workshop.

Livescribe Echo Smartpen

The Echo Smartpen is the latest model of LiveScribe pens (at the time of writing). It works like a 'normal' pen in that it uses normal ink, and writes on paper. However, the pen uses Anoto technology meaning that it can record what is written on the paper in digital format. The smartpen has a built in infrared camera that detects the unique Anoto pattern. The pattern is made up of small black dots that are almost invisible to the human eye and so does not distract the user or affect the readability of the text. The camera can detect what the users writes and where on the paper this is. The pen can then be plugged into a computer (Mac or PC) using a USB cable to upload the data to the LiveScribe Desktop software (which can be downloaded for free). In addition to this, the LiveScribe pens can also record audio when notes are taken (an optional feature), meaning that the audio and notes are linked.

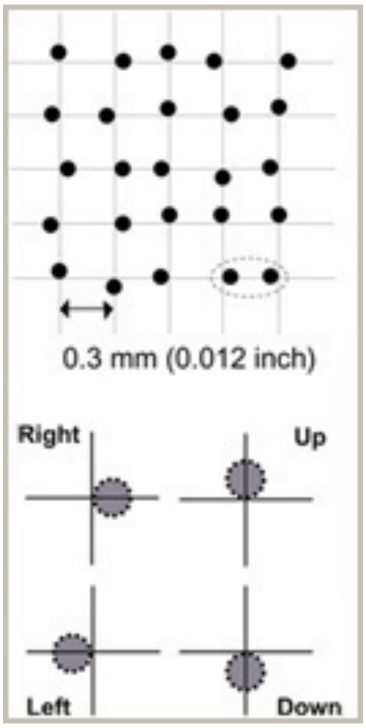

Figure 85 - Anoto Paper Pattern (zoomed)

Once the notes have been uploaded, the individual pages can be viewed electronically as a pencast pdf. If audio was recorded this can be played back. The interesting feature of this technology is that the audio and text are linked. Text that was written during audio recording shows up in green, and when clicked the associated audio will begin playing (which can then be skipped through as needed using controls on the screen).

Figure 86 - Echo Smartpen

In order to share the pen and audio data the pages can be exported as pencast pdf files with the audio embedded, as simple pdf files without audio, or as separate audio files. The pencast pdf files can be viewed in Adobe Reader X (and later versions). The desktop software also allows for searching of the data. The text recognition is quite reliable and this therefore becomes a useful feature. In addition to this, with the purchase of a plugin, the text can be exported as a text file where the writing is converted into ordinary computer text.

In addition to the desktop view of the data, playback can be carried out through the notepad itself. If you click on written text with the pen it will play back the associated audio (see Figure 87). Special 'buttons' on the page can then be used to skip through this or slow down the playback speed. Within each notepad further interactions can be initiated by clicking on a printed control panel at the front and back of the notepad. This includes a calculator (see Figure 88).

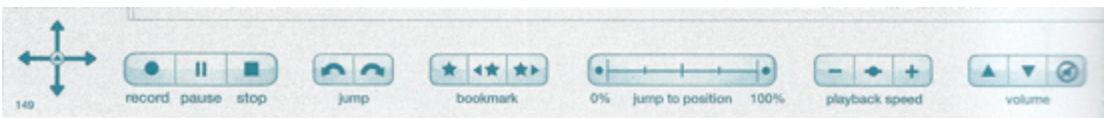

Figure 87 - Control Panel on Each Page

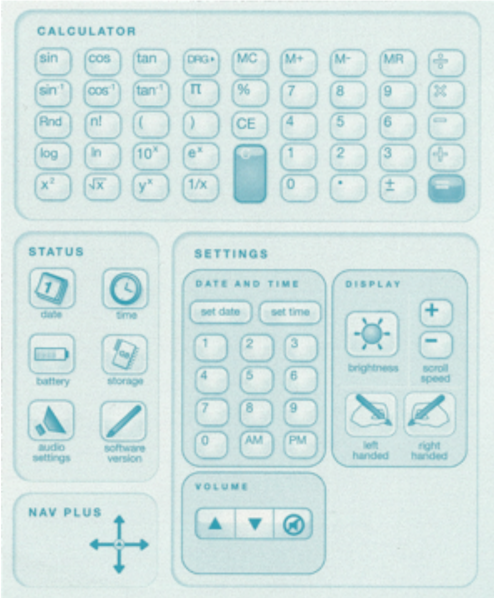

Figure 88 - Control Panel in the Notebooks (buttons are 'clicked' by touching them with the pen)

Motorola Xoom

Today there are a number of tablet computers on the market, including the Apple iPad and a range of Android devices by companies such as Samsung and Motorola. It was decided to go for an Android tablet as these are more flexible in their operation, and apps can be developed and released more easily.

The tablet used within the studies is the Motorola Xoom. This was chosen as it can be plugged into a computer to transfer data without the need for additional software. Alternatives such as the Samsung Galaxy Tab 10.1 require software to be installed in order to achieve this (Airbus does not allow external software to be installed on their machines). The chosen tablet needed to have 3G capability as the WiFi at Airbus cannot be accessed by external devices for security reasons.

Figure 89 - Motorola Xoom

Applications

Much of the potential of tablet computing is linked to the apps available for download. Therefore a number of apps were selected and installed on the tablet in order to provide a range of possible uses. The selection of these was based on the needs and requirements elicited through the ethnographic work and participatory design session. The main apps were as follows:

Skitch: This tool allows simple drawings to be created and shared through email or Evernote. The key feature that makes this app potentially useful for software development is the ability to upload photos or files (or take photos directly) and annotate these with the sketch tool (which included text entry, free sketch, boxes, and arrows).

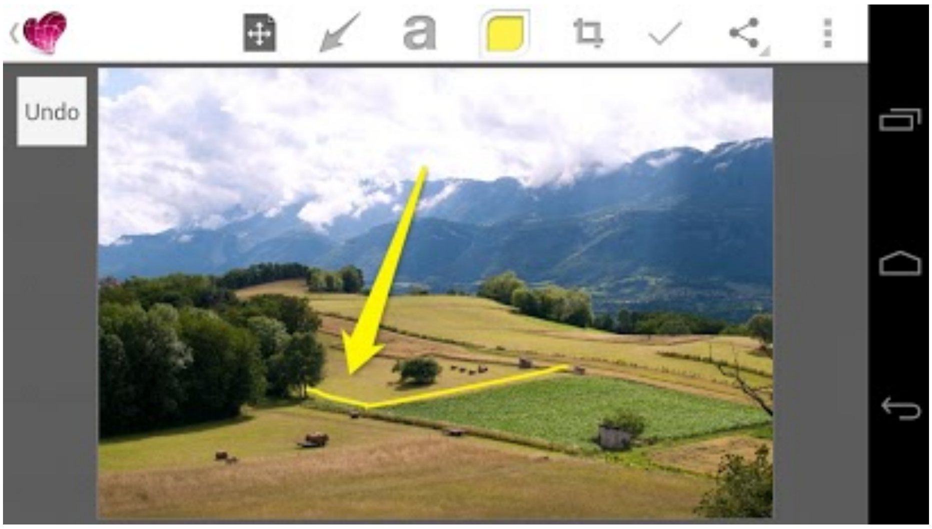

Figure 90 - Skitch Screenshot (from https://play.google.com/store/apps/details?id=com.evernote.skitch)

Evernote: This is a tool that allows people to share virtual notebooks. The notebooks can contain all sorts of media including Skitch files, text, audio, and photos and these sync across a range of devices, from phones to laptop. Notes can also be accessed via the web.

AudioNote: This app allows users to take typed notes whilst recording audio. Like the smartpen, the audio is linked to the typed notes. The android version does not allow sketches to be linked to audio, however this is available for the iPad/iPhone.

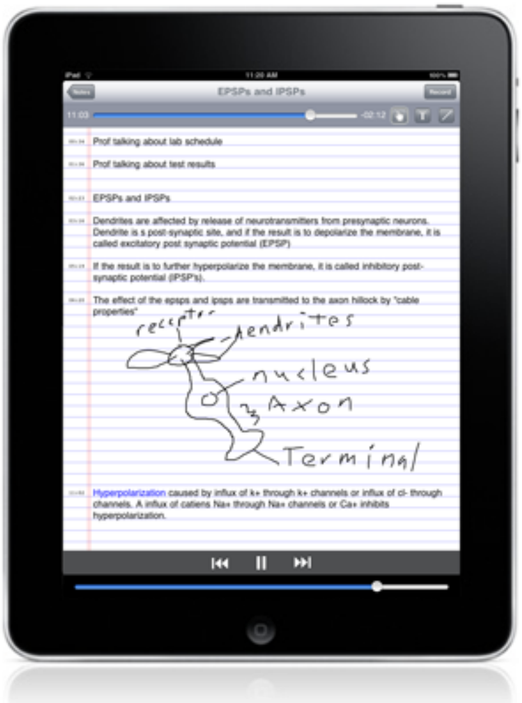

Figure 91 - AudioNote on iPad (Playback screen) (Luminant Software)

In addition to these apps, more general collaboration and productivity apps were included such as a RedMine app (to allow access to the RedMine instance at Airbus/SDC), Skype, and WebEx (again the company standard web conferencing software).

In addition to these apps, the tablet was set up with a Gmail account that participants could use (or they could log in with their own account). Money was added to the 3G account to cover internet access.

8.3 Evaluation

8.3.1 Introduction

In order for the evaluation to be as realistic as possible it was decided that the tools should be used by team members working on real projects over a prolonged period of time. The opportunity arose to align this work with a software development project that was just being ‘kicked off’. The original aim was for a selection of team members to use the pen and tablet for a two week period at a time over a course of two or three months.

8.3.2 Method

One of the key features established during ethnographic work was the need for flexible and lightweight tools. For this reason, it was decided that the users should be given a simple introduction to the tools and their features, with the focus on them being able to ‘appropriate’ these to their work processes.

Participants

Recruitment for this stage of the design process was a problematic process, as by this phase the external development company (SDC) that much of the previous work had been carried out with were unable to commit developers to take part (as has already been discussed). As developers are one of the key stakeholders it was necessary to identify someone at Airbus who could fulfil a similar role to this. Fortunately a member of the Methods and Tools team 'C' was on a secondment to the development company during this time and it was possible to recruit them for the study.

In addition to this it was necessary to get a key user to take part in the process. In this case 'A' was recruited as they were working on the same project as C and despite being a business lead for the project, they were also taking a role as key user (this flexible definition of roles is common).

It would have been preferable to have had a larger number of participants, but due to the limitations of only having one of each technology (due to costs) it was deemed better to work with two people over a longer time period, than to swap devices regularly between a larger group. This was because it was desirable for the users to have time to build familiarity with the tools and have time to incorporate them into their work practices.

Process

Once the participants were selected the tools were demonstrated to both of them. This was initially going to be carried out in two separate sessions but the opportunity arose to do this in a single session with both users. Each tool was introduced briefly and the key features explained. This was not carried out in detail in order to avoid overwhelming the users whilst also trying not to influence them too greatly. The idea was to allow them to make use of the tools in their own ways. With each device a brief summary document was provided that gave further details of the basic features and usage procedure.

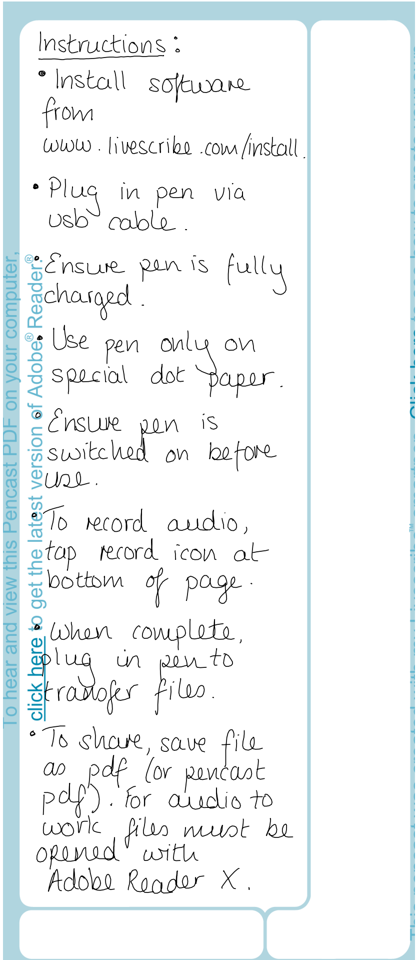

Figure 92 - Pen Instructions

8.3.3 Phase One

Each participant was given the tool for a two-week period. A had the pen, and C the tablet. They were asked to use this when it suited them during this period. Observations were not made due to the need to avoid biasing their use. If a researcher studying the use of the tool was always watching, they may feel pressure to use it. Yet in this evaluation it was important to understand not just how they used the tool, but 'if' they used it.

In order to gather their opinions on the tool an interview was held at the end of this period (individually). The interviews were semi-structured and were designed to get feedback on not just how they used the tool and their feelings on it, but also on any issues that might have occurred when trying to use it in the work setting, and ways that they would change the tool if they could.

At the end of the interview they handed over the tool and were asked for consent for the data they had generated with it (files etc.) to be examined. This data was then downloaded to a laptop, before the devices were wiped. The participants were then given the alternate technology to use.

8.3.4 Phase Two

This second phase was initially designed to last for two weeks, however, due to the decision to only involve two participants, it was later decided to allow them to continue for a further two weeks (a month in total). At the end of the first two weeks semi-structured interviews were carried out again, with the same focus as before. However, this time it was possible to probe comparisons between the tools. Finally, after the full month had passed, a final interview was carried out to see the effects of extended use of the tools.

8.3.5 Analysis

The analysis of this data was qualitative and high-level. The interviews were recorded and transcribed so as to identify themes across the data.

8.3.6 Findings

Overall the participants were quite clear that their preferred device was the pen. One participant was so excited by the device that they arranged to demo it to the European head of the department (on a scheduled visit to Filton). Unfortunately this meeting had to be cancelled, but this highlighted A's enthusiasm for the pen.

A: Oh I thought it was excellent. Especially compared to the tablet.

The reasons behind these feelings were probed in the interviews as well as how much the devices worked within the context. Attempts were made to address areas such as collaboration, sharing, recording, and flexibility. However, unanticipated issues such as ergonomics and usability also arose.

Ergonomics & Usability

Xoom

Many of the comments about the tools linked more directly to their ergonomics and usability. For example, both participants mentioned frustrations with the tablet 'going to sleep' and the awkward location of the power button at the back of the device (you would need to pick it up and turn it around to access it). The screen was set to turn off after a set period of activity (for power saving) and then this button would need to be pressed to reactivate it. The location of the button is a particular feature of the Xoom and other devices such as the iPad and Samsung Galaxy have a more accessible button. However, the tablet turning off in the first place is perhaps not ideal when taking notes in meetings.

(Xoom) A: If you are in a meeting it sleeps every 5 minutes so…and then the locking thing…

Typing on the Tablet

Another frustration was the issue of writing on the tablet. A tried using the notes feature (AudioNote) to capture meeting notes, but they found that the typing was difficult. As a result of this they even resorted to retyping the notes they had made onto their computer.

(Xoom) A:…But the problem I have is I couldn't get used to the touchscreen typing. So there were usually a lot of mistakes.
V: So you transferred it to your laptop and typed it in?
A: Yes.
V: So rather than writing off a notepad into your computer you just typed from the tablet?
A: If I was comfortable with the typing on it then I think I would just email the whole thing.

Drawing on Tablet
Both participants commented on the fact that drawing on the tablet with their fingers was difficult.

(Xoom) A:…Now the problem with this one is when you want to write things it's too thick. You can't use it. I would want a thin pen that I can write loads of things with, or I want to draw or something, maybe a picture of a wing, or some equations here and some explanation.

In general the feeling was that the tablet was too frustrating to use. When asked about the Xoom the responses from the participants were as follows:

C: It's useless.
A: The tablet, it's too fussy. It's not very, it's too awkward to use.

Whilst previous observations had highlighted the employees resilience to problems with systems, this appeared to only be the case if these were outweighed by the benefits. In this case the tablet did not seem to provide enough benefit to get beyond these frustrations.

Pen
While frustrations were raised about the tablet, the pen was deemed a more natural product to use.

(Pen) A: It flows naturally. What you're used to doing. It's not fiddly.

(Pen) A: I'm used to writing. It just enhances what you're already doing and what you're already comfortable with. There is no difference between using this and my ordinary pen and paper and the pen has this extra feature of recording the conversation so I think that's just great.
V: Did it change the way you wrote notes?
A: No I tried not to change the way I write. The only thing I do is press the record button when I'm writing.

The way in which the pen so closely reflects normal practices appears to have made it easy and efficient to use. Yet the added 'prosthetic memory' function of audio recording provided added benefits. Here there was little trade-off between the ability to retrieve information and the efficiency of capturing it.

In general the usability and feel of the pen were not criticised, but A mentioned hearing the scratching sound of pen when listening back to recordings. This can be rectified by using an external microphone (you can purchase this from Livescribe) but this was not tested during these evaluations.

Both A and C mentioned issues with the battery life of the pen. Having used a separate pen (the same make and model) this has never been an issue (it generally lasts for around a week without charging), so it may be that either the pen had a fault, or the participants were using it for much longer periods of time.

Software

Whilst the pen itself received very positive feedback, the software was not as well received. A mentioned the need to 'click' a number of times before accessing the data. Some of these clicks were linked to registering the pen, but A did not feel comfortable doing this for security reasons.

(Pen) A: The software on the computer there are at least 4 clicks before you can actually access your data. So there is, it tells you about registering, it tells you about updates, it tells you about connecting to the internet and you click answer, answer, answer. I'm not very sure how safe it is to register your pen. Would it transfer your data to somewhere on the internet. I really don't know.

(Pen) C: It took me a bit of time installing the software. First you have to install the software and then plug the pen in. I missed that point so that caused me some problems But I eventually sorted it out. But it took me one hour.

Work Practices

In general it appeared that the pen fitted better with both participants' own personal working practices. As has already been seen, the ability to use it as a pen seemed to make it very natural. However C in particular felt that they did not make the best use of it due to their tendency to not take many notes:

(pen) C: Yes because, err, personally I don't write very much during the meeting so as I understand, if you write something then it starts recording and if you want to..if you point the pen at that point you have twenty minutes of recording. So I think the recording capability is useful if you write a lot. If you just write a few words during a meeting then you have a word here and 20 minutes of conversation and another word here and another twenty minutes. In that case I don't find it very useful. But for people that write a lot.. I had a chat with [course mate]. Do you know [..]? (I: No). [They're] an EngD. They write a lot and think it would be really useful.

The pen's functionality does rely to some degree on taking notes to index the audio, thus some employees may find that it does not work as well for them. However, from previous observations it could be seen that the aerodynamic engineers tended to take a lot of notes in the notebooks that they carried with them. Software developers may not be so prone to these behaviours.

Privacy and Security

During the interviews both A and C brought up the issue of security. This linked to problems with recording audio on sensitive subjects. A highlighted that this was generally 'product' design meetings (i.e. those where wing design is discussed) rather than software development.

(Xoom) A: Recording, taking pictures...well I guess it's mainly security. A matter of what is discussed. There are meetings and then there are other meetings where you would use it in a development environment. When you are developing software. It could be of use. But when you're developing a product…like an aircraft it would cause problems.

A stated that they announced their intention to record the meeting before they began. They didn't have any issues with people refusing to be recorded during the evaluation but could envisage situations where it may be a problem.

A: Yes before every meeting I usually announce that I'm going to record it and they don't have a problem. If there's a senior manager presenting something confidential then there might be.

Aside from the recording there were also issues of the software on the pen linking to the Internet (although data is not shared unless specified by the user). A stated that they would rather the pen did not connect to the Internet at all. This was mainly concerned with Airbus considerations.

(pen) A: I would prefer it not to connect to the internet at all.
(pen) A: I think for Airbus because you never know if your data goes on the internet who might be hacking it so you want it to stay on your computer.

However in the third interview (after using the pen for a month) their attitude towards it seemed slightly different.

(Pen) A: *Connected to the cloud. Oh that would be very good actually. Upload everything you write to a cloud. So you're basically writing in a virtual notebook. So if you lose your notebook…it's being backed up continuously.*

These concerns regarding security of data were not unexpected. In fact the participants seemed less concerned than anticipated about these issues.

Connectivity

Both participants reflected on issues with connectivity of the devices. A wanted to send some drawings to someone at SDC (in response to them sending a picture taken on their phone) but couldn't easily transfer from the pen to the laptop (it would need to be plugged in). They therefore expressed a wish for wireless connectivity.

(Pen) A: Yes so say somehow you could have a send button here connected to that, you could send that page directly to that account.

Whilst the tablet was set up with a Gmail account to allow documents to be shared from it quickly this also had problems. C mentioned that they couldn't access the work accounts that they would normally use and this was a cause of frustration.

C: But I probably, in a working environment I usually use the Airbus account or SDC one but with this I can't access….

In general there seems to be conflicts between wanting ease of sharing i.e. a button to send notes, or a screen attached to the tablet wirelessly. But then they want to be sure that no sensitive information could accidentally end up on the Internet. This is something that could be made clearer through design and training.

Examples of Use

Both participants were asked to discuss examples of the use of the technology. Unfortunately there were not as many examples as anticipated due to the short time period in which they had the technology.

A had a meeting where another team member showed them the steps for carrying out a process. Afterwards they listened back to the notes. In fact A stated that they had listened to the notes the night before the interview occurred as they had to carry out the process during that day's work. Thus it served as a reminder.

A also used the pen when explaining a concept to C which involved them drawing diagrams. The aim was to send C the notes but at the time of interview A had not yet sent them.

C had not used the tablet much but enthusiastically discussed using the pen for their EngD work. They had used the pen to create a 'rich picture' of the software development context and then imported this into a piece of coursework.

(Pen) C: And then I found it quite useful an assignment to build a conceptual model of what is going on in this project. I used it to build a conceptual model and a rich picture. I could draw it, then download it as a pdf, upload it as a pdf on my laptop and then put it in the assignment as a pdf.

Examples of the notes taken cannot be included in this thesis for data security reasons. However meeting notes from A (made on the Xoom) showed how they wrote short notes during the meeting, listing tasks and key issues. They were not able to use bullet points (a noted source of frustration) so instead used numbers. These improvised bullets corresponded in general to tasks to be completed. In total the notes did not take up more than a page.

After a month of use C had rarely used the tablet, but A had continued to use the pen. This was for meeting minutes only. A also stated that they had only used it for face-to-face meetings with developers as other meetings were carried out over the phone. Using the pen in these instances was not possible.

A (Pen): I've used it a couple of times again with our sub-contractors but I cannot use it…it's difficult for me to use when in a telecon… So I guess that's the reason why I mainly use it with our sub-contractors as we have face-to-face, whereas anything else project partners are on the phone.

This is an issue where the pen does not meet the requirements to be flexible for use in many contexts. Whilst a teleconference held over a speakerphone can be recorded, if headphones are plugged in (which is often the case at Airbus where engineers hold calls at their desks) this is not possible.

Sharing

An interesting finding was that whilst both participants were incredibly positive about the pen and its potential, neither had actually shared any of the notes generated with it during their development work (as was also the case with the Xoom). However, they could envisage this being useful in the future.

(pen) A: I mean you could imagine how it would work, say I'm in a meeting and I'm trying or someone's explaining to me or I'm trying to explain to them. I could very quickly do a drawing and you can put some equations on it, take a .png, distribute it and perhaps I could use it in a presentation later. So it would be a very useful function, yes.

(Xoom) A: …I can see the benefits of doing some collaborative work. Of course not developing anything on it, but things like exchanging ideas, pictures, notes. It could be a good collaborative tool.

Both participants seemed concerned as to whether people would listen to the audio if it was shared:

(pen) C: You see here, people don't record meetings. I mean they could use a normal recording device, but they don't do it. I think mostly because they don't have enough time to listen to the recording after meetings and things like that. I think it's more suitable for lectures and students than professionals.

(pen) A: Err, I guess it's because these are lengthy conversations and I do not see how listening would be without the context. But yeah it's something, I wonder if that would change it if you send the pdf along with the recording and I guess it would work.

This last comment hints at a lack of understanding of the way in which the pdfs were shared. Did A believe that when sending the audio it was not linked to the notes? It is clear that they had listened back themself so were aware of the way in which pencasts worked, yet they weren't sure how the sharing would work.

Overall this lack of sharing during the evaluation was disappointing, but there was enthusiasm for the concept of it. Given a longer evaluation period instances of sharing may have occurred. However, in order to be a beneficial tool the notes do not have to be shared, as listening back to your own notes can provide a reminder of what was discussed and thus aid traceability.

Ad-Hoc Meetings

One of the key requirements established during the earlier studies was for something that could be used in ad-hoc meetings. The main way in which these tools would meet this need is in their portability. However, when asked if they had used the pen in any ad-hoc meetings, they had not. But this may be more due to the fact that instances of ad-hoc meetings had not occurred during this period.

A: I've used it in a number of meetings. I've not used it in an impromptu meeting anytime, no.

Apps
Neither A nor C used any other apps aside from the note taking app (AudioNote) when using the Xoom. This was disappointing as they had both been introduced to them. However this finding in itself highlights the potential problem with a tablet. Despite all the apps available, people may not utilise these. Whereas with the pen, the functionality is more simple and obvious to the user.

Bringing Own Devices In
Whilst one option may be to encourage a company to purchase devices such as the smartpen or tablet, it is also possible for employees to utilise tools that they already own. C discussed people using their phones to help record meetings:

I: So you use your phone for work? Is that something you are able to do at Airbus?
C: I'm not using it for work. I use my gmail account for work actually, yes.
I: Have you ever done something like take a photo on your phone and use it for work?
C: Yes. I've done it at university. Taking a photo of drawing on a whiteboard and sharing it by gmail.
I: And could you see yourself doing something like that here…?
C: Well I've seen people here doing it. I've seen (a SDC developer) doing it…I remember when we were doing the Sprint planning every week. [They were] taking a photo of the whiteboard at the end of each meeting.

I: Do you think people might bring in their own ones if they had them? Would you, if you had one at home, bring it into work?
A (pen): Yes I would.
V: And do you think Airbus would be ok with that?
A: Hmmm I think you'd need to convince the management level. Cos it's a hazard. It's a security….

Both seemed happy with the idea of bringing in devices that they already owned (such as a phone or the pen) but A was not sure how well this would be received at Airbus due to security issues.

Future Use
Due to the limited duration of the evaluation period, both participants were asked how they might use it in the future.

(pen) A: I see myself using it. If it's not too expensive I was thinking of buying it for myself.

Regarding the tablet, C saw it more as an entertainment tool.

C: You could use it for entertainment or social networks or seeing videos …. It is a good device for entertainment rather than a working environment.

Both could see a future use for the pen but not the tablet.

I: If you were given the tablet for work do you think you would use it?
C: No not to do this kind of work.
I: But if you were given the pen?
C: Yes I would use that probably.

C was probed about uses for the tablet, but felt happy enough with the features on their phone.

C (Xoom): Er definitely not. The feature I got here, this feature on my mobile now…I just use my phone. I can read my gmail account, get google doc, maps, can take pictures. So I don't see any reason why I should get one of these.

8.4 Summary

The pen appeared to be the clear favourite and it would be particularly interesting to investigate its use in more detail. For example, the natural progression from this point would be for the company to purchase a number of pens for more extended evaluations and possibly a more formal deployment.

It is unfortunate that it was not possible to study the use of the tools over a longer time period, as both participants hint that they a) would probably share data in this period and b) would probably get more used to them. However, time in the company was coming to an end and thus it was not possible.

From the findings, it seems that there is certainly potential for the pen to be useful in the software development teams (less so with engineers working on more secure wing data). The ability to record meetings, especially explanations seems promising.

8.4.1 Meeting Requirements

These technologies were identified for deployment as it was hoped that they would meet the requirements outlined earlier in this work, namely the ability to be flexible and lightweight in use whilst allowing design decisions and rationale to be recorded automatically. This was in order to meet the higher level needs of avoiding misunderstandings and aiding traceability, which in turn link to the use of regular informal communication which was not being represented in design artefacts. In addition to this it was hoped that the tools would be simple enough to fit (or be appropriated to fit) existing design practices.

The next section will provide an overview of the success of each tool as well as using the results of the evaluations (and experience from the ethnographic work) to identify how well they met the requirements specified in Chapter 6 and the additional requirements identified in Chapter 7.

The Smartpen

The pen seemed to fit into existing work practices as the engineers could use it in the same way they would use notebooks. It also allowed better recording of decisions. However, this potential was not fully utilised during the trial period as only A revisited the audio. The device was lightweight in that it was not designed for a specific purpose, and could be used in a number of ways (i.e. for drawing, writing, and other notation).

The pen was suitable for use in a variety of contexts of use, but there were problems with using it in audio conferences when headphones were used.

Table 8 - SmartPen Requirements Analysis

Functional Requirements		
1. Support collaborative work that is happening both face-to-face and remotely.	Medium	It can support recording of face-to-face meetings and remote meetings but only if a speaker is used
2. Support collaborative work that is happening synchronously and asynchronously.	Medium	The pen can record synchronous meetings. Meeting recordings can be shared asynchronously.
3. Allow users to initiate system use at any time.	Medium	The pen and notepads can be carried and used anywhere at any time. However there were problems with the pen battery.
4. Provide access to the system in a number of locations (i.e. through portability)	Medium	The pen and Anoto notepads are easily portable. Smaller notepads can also be purchased.
5. Provide the ability to capture a range of design artefacts across the design lifecycle.	High	The pen can be used to create a record of discussions throughout the design process. These can be used as artefacts themselves or the notes can be used to help generate more formal artefacts.
6. Allow all stakeholders to create, edit, and share artefacts	Medium	If all stakeholders are provided with a pen, then they will all be able to create, edit, and share the documents created.
7. The system must support the capture of design decisions (both formal and informal)	High	The pen can capture handwritten notes as well as audio records of the decisions made.
8. The system must support the sharing of design decisions	High	By sending pencast pdfs, the notes and audio can be shared with the rest of the team.
9. Provide facilities for additional annotations to artefacts created outside of the system.	Medium	Unless artefacts are printed onto Anoto paper this isn't possible. Currently it is not possible to print like this.
10. Provide facilities for	High	Notes can be re-annotated with

additional annotations to artefacts previously created using the system.		the pen after initial creation. However this is only the case with the original document (as copies won't be on the Anoto paper).
11. Support the creation and sharing of informal design artefacts	High	Any form of written artefact can be created and shared with the pen.
12. The tool should be compatible with existing work practices	High	The pen can be used in meetings as a normal notepad and pen would be. The audio recording may not always be allowed though.
13. Allow the end users to easily share their knowledge	Medium	End users can draw diagrams and record accompanying audio explanations of the domain knowledge.
14. The system should not enforce set processes on users	High	The pen use can fit in with existing project processes and does not enforce a set procedure.
15. The system should not enforce set roles on users	High	The pen can be used by any stakeholder and the functionality does not change across roles.
16. Provide means for the design rationale to be converted into or used in the development of formal specifications	Medium	Whilst it is not an automated process, the notes from the pen can be used to support the creation of formal specifications. Diagrams can also be copied and pasted from the pdf files.
Non-Functional		
17. The system should be responsive and quick to load.	Medium	The pen can be switched on and used instantly. However the software that is needed to upload and share the documents can be slow. There is also a potential problem with battery life.
18. The system should reduce the amount of software that needs to be installed on machines	Medium	In order to share the documents with others (as pencast pdfs), software is needed. This can be downloaded from the internet but requires admin rights to install.
19. Avoid the use of cloud based storage	High	Whilst Livescribe provide a cloud repository for pencasts, pencast pdfs can be shared via the Airbus email system.
20. Do not require access to WiFi	High	The pen does not require access to WiFi.
21. The system should be	High	PDF is a standard document type

compatible with inputs and outputs of other systems.		that is compatible with most systems. Audio can only be replayed when the document is opened in Adobe Reader X.
Domain		
22. Allow users to create complex representations such as diagrams, graphs, and algebraic notation	High	The pen can be used to create any freeform annotation that the users would write on paper.
Additional Requirements		
23. Make capture of decisions as simple as possible (perhaps automatically)	High	The pen allows audio to be captured automatically.
24. Reduce barriers to system uptake	High	The pen fits into existing working practices fairly easily. However the inclusion of audio recordings may make some people feel uncomfortable.
25. Support the ability to create formal documentation automatically or with as little effort as possible.	High	The pen provides the ability to record decisions automatically, but it will require effort to convert these into formal documentation.
26. Support the creation of documentation for management purposes.	High	This process will require additional effort using other tools.
27. Allow requirements to be represented and communicated visually.	High	The pen allows users to draw requirements whilst providing an audio commentary.

Remaining Challenges (Smartpen)

Despite a number of the requirements being met with the pen, there are still issues related to the recording of audio. For example, Airbus prohibits the use of audio recording without prior permission (although this was gained for the duration of this research). Perhaps if the benefits of the device could be shown, they may relax these rules in software development meetings, especially if they can be assured that the audio will not leave the site. In addition to this, audio cannot be recorded when a phone or headsets are being used in teleconferences. The engineers often hold conference calls at their desks where headphones are necessary.

There are additional issues with installing the software for the pen. Currently it is not possible to install software on the work machines so for this study both participants used their own personal laptops (which they took to work). In the future the software could be added to the list of 'approved software' and then this issue would present less of a challenge. Without this step it would not be possible for the pen to be used without employees bringing in their own laptops.

These barriers were anticipated but there are solutions to these that could be overcome with policy changes. What is positive about the pen is that it can fit well into existing work practices, requiring little adaptation on the part of the user.

The Motorola Xoom

The engineers did not seem to find the tablet flexible enough in use as they could not draw diagrams on it very well. In addition to this, they struggled to use it to take notes, as the typing feature was not natural enough for them.

The tablet could theoretically be used in a variety of contexts, but this did not occur due to the issues mentioned above. The engineers did not find it easy to use, and it could not support some features of their work.

Table 9 - Motorola Xoom Requirements Analysis

Functional Requirements		
1. Support collaborative work that is happening both face-to-face and remotely.	Medium	The tablet can be used to take notes in meetings (as well as providing other functionality). It can also be used to hold remote meetings (via NetMeeting). Audio cannot be recorded when using a phone or headphones.
2. Support collaborative work that is happening synchronously and asynchronously.	Medium	The tablet can be used in synchronous meetings. It can also be used to share documents between meetings (or if someone has missed a meeting).
3. Allow users to initiate system use at any time.	Medium	The tablet can be used at any time but switching on the tablet can be akward.
4. Provide access to the system in a number of locations (i.e. through portability)	Medium	The tablet is portable and can be carried to different meeting locations.
5. Provide the ability to capture a range of design artefacts across the design lifecycle.	High	The tablet can capture 'written' and typed notes. It can also be used to store other forms of artefact such as pdf files and images.
6. Allow all stakeholders to create, edit, and share artefacts	Medium	Stakeholders can use the tablet to create, edit, and share notes (and images). Those who don't have a tablet can receive the files created with the tablet.
7. The system must support the capture of design decisions (both formal and informal)	High	The tablet can capture notes and audio in any type of meeting.
8. The system must support the sharing of design decisions	High	Any notes made on the tablet can be shared with any other

		stakeholders.
9. Provide facilities for additional annotations to artefacts created outside of the system.	Medium	The tablet allows image files to be annotated using a drawing package.
10. Provide facilities for additional annotations to artefacts previously created using the system.	High	Notes that are created in the note taking apps can be edited and added to.
11. Support the creation and sharing of informal design artefacts	High	The note taking apps can be used to create notes or drawings. In addition to this, the tablet can be used to photograph other informal artefacts such as post-it notes.
12. The tool should be compatible with existing work practices	High	The tablet can be used in meetings and at desks. However, it requires use of the tablet for writing/drawing rather than a pen and paper.
13. Allow the end users to easily share their knowledge	Medium	Notes can be shared from the tablet instantly via email. They can also be added to other repositories that have a web interface (or app).
14. The system should not enforce set processes on users	High	The tablet can be used in a number of ways. However it does require text input through a keyboard and drawing with a finger or stylus.
15. The system should not enforce set roles on users	High	Anyone can use the tablet in any manner.
16. Provide means for the design rationale to be converted into or used in the development of formal specifications	Medium	Notes and audio from the tablet can be used to support the creation of more formal artefacts. Typed text can be copied and pasted, as well as any diagrams that have been created.
Non-Functional		
17. The system should be responsive and quick to load.	Medium	The tablet can suffer from slow responsiveness at times. It also turns the screen off after a set period which means users have to spend time switching it back on.
18. The system should reduce the amount of software that needs to be installed on machines	Medium	The Motorola Xoom can be plugged into a computer and files transferred from it without specialist software (other tablets

		require software for this).
19. Avoid the use of cloud based storage	High	It may be time consuming to plug the tablet into a computer. In this case files can be transferred through the cloud (via other email systems). This is not as secure.
20. Do not require access to WiFi	High	The tablet can function without WiFi but it will require 3G to access the internet, which the company may not feel is secure. Alternatively files can be loaded from the tablet onto a PC.
21. The system should be compatible with inputs and outputs of other systems.	High	The tablet can be used to view a variety of file types. However the files it generates may not be compatible with other systems.
Domain		
22. Allow users to create complex representations such as diagrams, graphs, and algebraic notation	High	Users can 'draw' on the tablet with their finger or a stylus. However it may be difficult to create formulas in this manner. Drawing was also reported to be awkward.
Additional Requirements		
23. Make capture of decisions as simple as possible (perhaps automatically)	High	The tablet allows audio and notes to be recorded. However typing and drawing on the tablet can be challenging.
24. Reduce barriers to system uptake	High	The tablet requires some change in work practices, which may put people off using it. It also suffers from some usability problems.
25. Support the ability to create formal documentation automatically or with as little effort as possible.	High	Text can be copied and pasted from the tablet, however additional work would be needed to create formal documentation.
26. Support the creation of documentation for management purposes.	High	As with the above requirement, additional work would be needed to covert the output from the tablet into formal management documentation.
27. Allow requirements to be represented and communicated visually.	High	The tablet allows sketches to be drawn (but not entirely naturally) whilst audio is recorded. In addition to this, images can be captured which may assist with communicating requirements.

Remaining Challenges (Xoom)

Overall it seems that the usability and ergonomic problems with the tablet outweighed any of the other benefits that it may have provided. Therefore it would be recommended that an initial period of evaluation could have been carried out looking at these issues with the devices prior to deployment.

As well as the Smartpen, the Motorola Xoom also had issues with recording audio, both for policy reasons, and the lack of ability to record audio when using headsets.

However, one benefit with the tablet technology is that new devices are regularly introduced and the app market provides a regular source of new software that could overcome some of the other issues found.

8.4.2 Other Technologies

The two technologies selected from the workshop were used within the evaluations but it is important to note that other technologies exist that could also meet the requirements that have been identified.

The Livescribe 3 SmartPen[1] is an updated version of the Echo Smartpen used in these studies. It comes with a companion Mobile App that allows further features to be added to notes, such as tags, and additional resources (i.e. photos). Whilst these added features don't address the remaining challenges (such as recording teleconference audio) they may allow for more comprehensive records to be created.

There are now a wide variety of tablet devices available to purchase (such as the Samsung Galaxy Tab[2], iPad Mini[3], and Microsoft Surface[4]. A number of these may overcome some of the usability issues with the Motorola Xoom (such as the location of the on button). There are also a range of stylus devices available that have smaller and more responsive pen tips than the ones available when these evaluations were carried out. This includes the Wacom Bamboo Solo[5].

There are also a variety of note taking applications on both the Apple App store and Android Play store. The Windows software available for the Microsoft Surface may also provide better compatibility with the software currently being used at Airbus.

8.4.3 Reflections on Method

This section will provide a reflection on the method of introducing technology into the workplace in order to evaluate its success, as well as the ways in which feedback on the use was gained.

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1 www.livescribe.com/uk/smartpen/ls3/
2 www.samsung.com/uk/consumer/mobile-devices/tablets/tablets
3 www.apple.com/uk/ipad-mini/
4 http://www.microsoft.com/surface/en-gb
5 http://www.wacom.com/en/us/everyday/bamboo-stylus-solo

Rather than introducing a single technology after the design workshops to gather feedback, it was decided that a comparison might yield more in depth findings. In fact it was possible to clearly see a preference between the two tools. Yet, whilst the Smartpen was the favourite, both participants were also able to identify issues with this.

Through trialling the technology in situ it was possible to identify potential barriers to the tool use. Some of these were anticipated (such as security concerns) and others less so.

The method used in the tool evaluation was somewhat different to the more observational techniques used in earlier work. The rationale for this was that the presence of a researcher might bias the frequency of use (given that they had been introduced by the researcher). However, the reports of use provided in the interviews were quite high level and vague and occasional observations may have been beneficial.

As has been mentioned in the previous section, there were a number of 'usability' problems with the tablet that could have been identified prior to committing to a deployment of the technology. In the future it may be worth having an intermediate stage where a number of different technologies are demonstrated (perhaps even in the design workshop itself) in order to identify these as early as possible.

It should also be noted that during this trial of the technologies, some logistical issues had to be bridged with short-term solutions. This included asking the participants to bring their own laptops into work (to install software), and providing 3G connection as the tablet was not authorised to be used on the WiFi. If the technologies were to be introduced more formally it is hoped that the software could be approved for installation on the work machines, and that the tablet would be authorised for use on the WiFi.

Chapter 9

Conclusion

9.1 Introduction

This thesis has provided a detailed description of a process for uncovering needs and requirements for support in collaborative teams. It has also explored a method for identifying existing technology to meet these. These have both been achieved through the use of a case study of collaboration within software development teams at Airbus. This final chapter will provide an overview of the work carried out, how it has answered the research questions, and the contributions that it has made.

9.2 Research Questions

This thesis aimed to answer three research questions (although these evolved during the research itself). The following section will briefly summarise how these have been answered, whilst the rest of the chapter will discuss this in more detail.

Q1. What techniques can be used in an industrial setting to identify areas for support in collaborative work?
This thesis has used a combination of ethnography and more focused data collection methods such as surveys and interviews to identify the needs and high-level requirements of collaborative software development teams.

Q2. How can users be effectively involved in identifying which existing technology could meet these needs?
A process for conducting workshops has been devised that exposes users to new and existing technology and encourages them to visualise new work practices that utilise this.

Q3. What are the collaborative needs of software development teams at Airbus, and can existing technology support these?
The software development teams being studied have needs relating to the flexible capture and storage of domain knowledge and system requirements. Technology was introduced to help them capture this, in the form of a Smartpen that records handwritten notes along with audio and a Motorola Xoom tablet with note taking apps. The pen was found to fit well with existing work practices, whilst being flexible to the different needs of individuals and projects. The tablet had a number of usability problems that inhibited its success.

9.3 A Process for Identifying Needs (RQ1)

This thesis has outlined a process for identifying needs and matching these to existing technology. This process has several stages (see Figure 93) each of which will now be summarised.

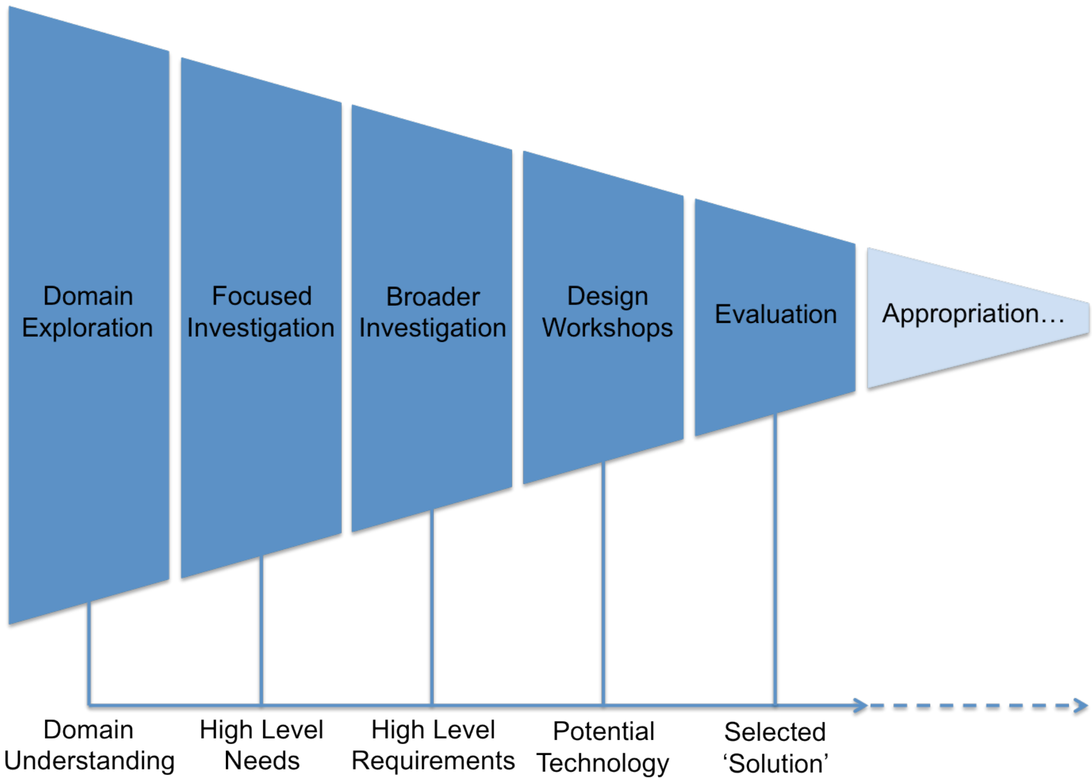


Figure 93 – A Process for Identifying Collaborative Support Needs and Exploring Existing Technology As Potential Solutions

9.3.1 Domain Exploration

When entering a context such as that at Airbus, it is important to build a detailed understanding of the everyday workings of the organisation. The complexity of the work processes and languages used means that it is not possible to pick this up easily. Instead, time needs to be spent acclimatising to the domain. Thus a period of time should be spent in what will be referred to as 'Domain Exploration'.

This stage took a traditional ethnographic approach to data collection, through acting as a member of the team, and carrying out informal observations and interviews. Through living the life of an employee, attending meetings, going to lunch, and having a desk in the offices, it was possible to get a good 'feel' for the work. Along with this, overviews from other engineers concerning the official processes, and the systems used were vital in building up contextual knowledge. Whilst these may not be considered to be 'natural' interactions, without them the context of work would be much more difficult to understand.

This is an opportunity to learn the language of the domain, gain an understanding of the organisation, the work outputs and interdependencies. Without this context it is difficult to understand the more intricate details of the work. This phase also allows working relationships to be developed which become useful in gaining access to people for later studies.

However, this stage was not useful for identifying the more in depth collaborative processes. Whilst an understanding of the interdependencies of the work was gained, along with the high level processes, it was not easy to access the finer details of this without more in-depth investigation.

9.3.2 Focused Investigation

Once an understanding of the domain has been gathered it, it is then important to begin to understand the intricacies of the work, and in this case, the details of the collaborative work. During this phase of the process it was necessary to take a more direct approach to observations. Rather than taking in the general context, activities were planned to get a better understanding of the work happening either behind closed doors, or through means such as email, which cannot be easily observed in a more casual manner.

A number of methods were attempted during this phase of data collection, including interviews, diary studies, and observations. Additionally a single project case study and different types of analysis were carried out. This included the more top down approaches of applying existing coding classifications to transcriptions of design meetings, as well as attempts to apply concepts from Activity Theory. However this did not yield as many insights as anticipated. Instead the approach of focusing on a case study and carrying out more informal bottom-up analysis, such as identifying themes over time, appeared to yield the richest insights. Thus it would be recommended that future applications of this process attempt to build a case study of a distinct design activity (such as a single project) and analyse this in a bottom-up thematic manner.

At the end of this phase it was possible to identify an area of focus (collaboration in software development) and a number of themes for further investigation such as means of communication, use of artefacts and occurrences of misunderstandings.

9.3.3 Broader Investigation

Having identified themes through the case study work it was important to build support for this by opening up the scope to a broader range of projects, roles, and locations.

At this stage a significant period of time had been spent in the field gathering contextual information and it was therefore possible and favourable to use some more direct and focused techniques to gather data. This included surveys and interviews. The findings from these could then be fitted into the existing understanding of the context.

This phase of the process succeeded in both providing support for the themes identified in previous phases, and creating additional insights. From this a set of needs could be identified, along with initial high-level design requirements for any solutions.

9.3.4 Matching Needs to Technology (RQ2)

Given a set of requirements, two potential options stand out for meeting these. Firstly, an organisation can choose to create their own bespoke tools, either developing it themselves or outsourcing this. Alternatively they can look to existing technology that may already exist. This thesis has focused on the latter of these possibilities.

The process proposed here evolved throughout the course of this work, as it was not the explicit goal when the research began. Initially the plan was to identify support needs and meet these in whichever way seemed most suitable. However it became clear over time that the needs of the teams did not require complex bespoke software to be developed due to the large amount of existing technology that could already potentially meet their requirements. Thus the focus of the research shifted to look at how existing tools could be matched to the identified requirements. The role of the design workshops became clear when it was felt that stakeholder input into the decision process was still vital, despite the time spent studying the users and the domain. Consequently, a scenario-based design workshop was developed that would present the high-level design requirements, along with examples of existing technology to enable the participants to begin to match their requirements to this technology.

In order to get the stakeholders thinking creatively and not being restricted by the current scenarios, a phase was introduced which involved envisaging their work 50 years in the future where money and physics were no limit. This was preceded by videos of 'visions of the future'. Then short video clips of a selection of existing technology were introduced which could bridge the gap between the current context and visions of the future.

Figure 94 - Workshop Process

The actual output from the workshops (the pilot studies and final workshop at Airbus) was not exactly as anticipated, as rather than producing scenarios using the technology presented, the participants instead took inspiration from it. Subsequently their scenarios often produced ideas based on technology that still did not exist, instead looking slightly into the future. Therefore when looking to establish the outcomes of the workshop at Airbus it was necessary to add a further stage of analysis, coding the discussions, identifying further requirements, and then using these to identify existing technology.

In addition to this, there were deviations from the intended workshop process such as impromptu discussions on existing barriers to technology, and useful design features, but these actually proved to be very important. Recommendations for future workshops would be to allow for flexibility in the process and also to develop guidelines for workshop analysis.

It should be noted that some of the methods used in the workshop at Airbus were specific to the particular requirements of the context. For example the time/space matrix was used as a tool to get participants to develop ideas for technology to support a range of collaborative contexts. This may not be applicable to all situations. A more generic recommended procedure for future workshops is as follows:

Workshop Preparation

Using requirements established in ethnographic studies, identify existing technology that could satisfy these. It may also be of use to include some additional technology that does not obviously meet these needs, to provide a contrast and potentially prompt unanticipated discussions and ideas. Also gather 'future vision' resources to present.

Workshop Process

Workshop Resources:

- A5 cards to present technology and high-level requirements/design constraints.
- A3 paper for drawing scenarios.
- Flip charts for group work.
- Audio/Video recording for later analysis.

Introduction: Introduce the concept of scenarios, demonstrating the concept at a high level. This phase could also include showing participants example scenarios to help provide a clearer vision of what to produce.

Initial Scenarios: Get participants to individually represent a current scenario of their collaborative tasks and present this briefly to the rest of the group.

Future Vision: Present (preferably visually) a short (~5 min) vision of the future to prompt the group to think more creatively about their own visions.

Future Scenarios: Ask participants to individually develop a vision of their scenarios in the future where money and technological limitations are no barrier. The aim of this session is to get the group to think more divergently and move away from current practices.

Technologies: Present current technology to the group using a combination of visual materials, and potentially live demonstrations.

Future Scenario (V1): Ask participants to individually develop a scenario that uses the technology shown (or inspiration from this) to try and achieve their vision of the future.

Future Scenario (V2): Get the participants to work in a group to discuss their ideas and develop one of the ideas or a combination of the ideas in more detail. This phase can be left flexible for the facilitator to direct as appropriate.

Optional Extras: If time allows it may be beneficial to have brief group discussions after the presentations of individual scenarios to identify commonalities or conflicts between them.

Workshop Analysis

The scenarios should be compared and the audio analysed to identify key themes within the scenario presentations and group discussions. Through this analysis further requirements and constraints can be identified, especially relating to specific reflections on the technology presented.

9.3.5 Technology Evaluation

Having identified the needs and potential technological solutions, it was important to evaluate the success of these. Through this it was possible to identify a preferable solution in the form of the Livescribe Echo Smartpen, albeit with some barriers which would need to be investigated further by the company (such as recording policies). However, had both examples of technology been rejected by the users, the output of this phase would feed into further requirements for technology and another workshop could be held.

9.3.6 Appropriation

This is not part of the prescribed process, but something that is an inevitable result of introducing technology. It is not something that this thesis has covered explicitly, however it is an important phase of technology introduction and should be considered within this process. You cannot necessarily design for appropriation, but you can design with the knowledge that it will happen. By introducing flexible and lightweight tools in this case study, the door was left open for unanticipated changes in use or within the context of work itself. Thus it is a recommendation that when carrying out a design process such as that described in this project, an awareness of the implications of appropriation should be retained throughout.

9.4 Reflections on Methods Used (RQ1)

RQ1 asks which techniques can be used to identify needs in an industrial setting. This section will reflect on the methods used, with a particular focus on their appropriateness to the industrial setting. It will then discuss some of the more general 'challenges' that were encountered when carrying out research in this setting.

9.4.1 Data collection methods

Planning & Flexibility

As already noted by (Crabtree, 2003), it is important during ethnographic research to remain as flexible as possible. Reflecting on this particular research project, it is clear to see the importance of this.

When carrying out observations, informal discussions or working as part of a team this cannot always be planned in advance and thus requires the researcher to be on site and ready to get involved at any time. For example, it was possible to be invited at the last minute to attend a teleconference (by simply picking up the phone and dialling in) where users were providing feedback on the latest software version release. This ended up being a vital 'observation' and is described in Vignette 6. In addition to this, when carrying out the 'Broader Investigation' it was necessary to carry out a series of semi-structured interviews with less than a days notice.

Whilst a degree of flexibility is needed, sometimes more formal routes need to be taken when planning data collection. This can mean delays in collecting data and may require permission to be gained from a series of gatekeepers. When setting up the observations of the Aerodynamic Engineers, it was necessary to gain approval from their managers, which in turn involved presenting the work to them. Then when capturing the aerodynamic design meetings it was important to gain approval to carry out these recordings as the discussions needed to remain secure. Eventually it was agreed that the meetings could be recorded but that these would need to remain on site.

Data Capture

The lack of permission to carry out video recording on site meant that it was difficult to capture work processes during observations. Instead detailed notes were taken, but unless these were revised immediately afterwards they were of limited used. During observations time was often spent assigning 'time codes' to the notes to link them with the audio. This was sometimes a distraction and reduced the time available for capturing contextual information. However, the Echo Smartpen detailed in this research is actually a useful tool for ethnographic work. As the audio and notes are automatically linked, more time can be dedicated to the note writing. In fact, the pen was used to capture the interviews described in Chapter 7.

9.4.2 More General Challenges

External Stakeholders
A particular hurdle in this project came in gaining access to the software developers. Due to the fact that key stakeholders in the development process were at an external company, issues arose with gaining access to them. Whilst the software developers themselves were seemingly keen to take part (sometimes asking for help in return), it was necessary to go through a gatekeeper at this company to officially ask for their participation. At Airbus the same procedure occurred but there were never any problems gaining this permission. This is probably due to the fact that it was a project funded by the company and had the official buy-in of the local managers. However, this external firm had no official links to the project and thus whilst they were enthusiastic about the work and very supportive, when a manager is considering man-hours and costs, priorities can be different. For this reason, despite early access going above and beyond expectations, they eventually had to decline requests. This was completely understandable but should serve as a warning when working with stakeholders from companies that are not directly supporting or benefitting from the research. Their continued input should not be assumed. Additionally, ways in which mutual benefit can be achieved should be considered. The mutual benefit in this project was the ability to provide advice on interface design. However this is likely to differ depending on the skills of the researchers carrying out the observations.

Participant Recruitment
When setting up the design workshops outside Airbus the process took around two weeks (booking rooms, and recruiting participants). In fact, the third session was arranged around five minutes before it took place (the opportunity arose and people were keen to help). Setting up the Airbus workshop took much longer (around two months). This mainly linked to recruitment, where there is a much smaller group of potential participants. To find three people who were available, and willing to take part, was much more challenging than sending an email to a mailing list looking for participants.

Gaining time with people is a key issue as in this company each employee has to assign their time to a project code. This research did not have a 'project code' associated with it and thus gaining more than 15 minutes with people could lead to issues such as what code they assign the work to. However, workarounds were normally found.

Problems were also encountered when sending out email surveys as the pool of participants was limited to a set of roles within a single company. Thus ways in which to encourage greater participation need to be carefully considered, such as getting manager or gatekeeper buy-in.

9.4.3 Lessons Learned

Overall being in an industrial setting presented a number of challenges when collecting data, namely in gaining access to the right people, and with recording in a sensitive environment. Given the opportunity to carry out this research again the process would be much smoother as a result of the lessons learned. These lessons are summarised below and could act as guidelines for future researchers.

- Spend as much time as possible on site, to gain visibility, and to be ready to collect data when the opportunity arises.
- Plan more formal data collection as early as possible, and build good relationships with key gatekeepers.
- Spend time building relationships with other workers in the domain as these links could be beneficial when recruiting participants for future activities.
- Look for ways to provide mutual benefit during data collection (such as taking part in meetings as a participant observer).
- Identify ways to target as large a population of stakeholders as possible when recruiting participants for research activities.
- Do not rely too heavily on external organisations that may not have a continued vested interest in the work.
- Take frequent notes after informal discussions as these details could be relevant when carrying out high-level data analysis (i.e. don't rely on memory alone)
- Test and refine methods outside of the organisation if necessary to avoid using up valuable time and resources within the domain of study.
- Build understanding through familiarity with case studies if the opportunity arises. This may allow a deeper understanding to be gained.

9.5 A Case Study of Collaboration in Software Development Teams (RQ3)

RQ3 asked what the collaborative needs of software development teams are at Airbus and how existing technology can support them. Through the case study carried out during this research it has been possible to look at the needs in depth and evaluate potential solutions.

Although collaboration in software development teams has been a focus of many past research studies, it is still an important and developing area of study and thus this thesis can provide relevant contributions to this field.

9.5.1 Characteristics of Collaboration in Software Development

The case study has been able to highlight a number of characteristics of collaboration in this particular software development environment.

Domain Knowledge -> The developers at Airbus often need to grasp difficult aerodynamic concepts in order to implement the systems. Through both the study of the aerodynamic engineers, and the involvement in software development, it was clear that the complexities of the software mean that the users (or a proxy for them) need to be closely involved in the development. However this communication is not as frequent or efficient as necessary.

Documents and Artefacts -> Whilst the projects officially follow a formal design process with set documentation and milestones, more informal documents and artefacts are being used in conjunction with these. These range from very informal post it notes to more formal user stories. These are required to support the more informal and flexible processes that are taking place within the development teams but are not officially recognised.

Misunderstandings and Traceability -> Whilst the teams are agreeing on decisions in meetings, the actual understanding behind these is often being interpreted differently leading to later problems such as wasted development work.

Communication Mechanisms -> The teams tend to use a variety of communication mechanisms, including face-to-face meetings, emails, and teleconferences. This fragmentation of communication (and ways for recording this) may be contributing to the misunderstandings occurring.

Summary

In order to avoid biasing the case study, literature relating to collaboration in software development was not studied in depth until after the ethnographic phase of this work. However, these characteristics and related challenges reflect a number of findings and recommendations from previous research. For example, the importance of domain knowledge and access to end users supports Chilana, Ko, and Wobbrock (2009) and Curtis, Krasner, and Iscoe (1988). In addition to this, the need to support recording of decisions mirrors the recommendations from Herbsleb and Grinter (1999) and Kraut & Streeter (1995).

9.5.2 Supporting Collaboration in Software Development Teams

Through further exploration of the nature of these characteristics and the associated needs of the teams, it was possible to begin to identify how to provide better support for them.

Lightweight -> Any solution should be lightweight. By this it is meant that it should offer simple, yet essential functionality that can be appropriated by the users to achieve a variety of tasks.

Artefacts -> Any solution should focus on supporting the creation and sharing of both formal and informal design artefacts between all stakeholders.

Traceability -> Linked with the ability to create and share artefacts is the ability to support the traceability of design decisions, again, both formal and informal. It should be possible to identify the rationale behind decisions that have been made.

Multi-Purpose -> Linked to the need for a lightweight tool, is the need for it to be multi-purpose. Software development has a number of different stages, and takes place in a number of different contexts (i.e formal, and informal ad-hoc meetings, co-located, and remote meetings). Tools for support should be appropriate for use in as many of these contexts as possible.

9.5.3 Requirements Specification

These needs were also developed into the following set of requirements:

Functional Requirements

1. Support collaborative work that is happening both face-to-face and remotely.
   Rationale: Software development work is carried out in a range of contexts, such as face-to-face meetings, phone calls, and net meetings
   Priority: Medium

2. Support collaborative work that is happening synchronously and asynchronously.
   Rationale: Software development work is carried out both synchronously (at the same time) and asynchronously (at different times).
   Priority: Medium

3. Allow users to initiate system use at any time.
   Rationale: Not all decisions are made in pre-planned meetings, thus the tool should be easily accessible to record ad-hoc discussions.
   Priority: Medium

4. Provide access to the system in a number of locations (i.e. through portability)
   Rationale: Meetings are carried out in a number of different locations such as the Airbus and SDC offices.
   Priority: Medium

5. Provide the ability to capture a range of design artefacts across the design lifecycle.
   Rationale: It is important that the tool can be used across the entire design process to avoid fragmentation of the design rationale across a number of systems.
   Priority: High

6. Allow all stakeholders to create, edit, and share artefacts
   Rationale: With a range of different stakeholders taking part in the design, it is important that all members can access design artefacts created by the system.
   Priority: Medium

7. The system must support the capture of design decisions (both formal and informal)
   Rationale: There is evidence of breakdowns due to design decisions being lost or recorded incorrectly.

Priority: High

8. The system must support the sharing of design decisions
Rationale: Once decisions have been captured it is important that they can be shared with the entire team.
Priority: High

9. Provide facilities for additional annotations to artefacts created outside of the system.
Rationale: Design decisions are often updated or require comments to be made on them. In order to be compatible with existing practices, the system should allow artefacts from other sources (such as Powerpoint slides or notebooks) to be annotated or updated.
Priority: Medium

10. Provide facilities for additional annotations to artefacts previously created using the system.
Rationale: Design decisions are often updated or require comments to be added to them.
Priority: High

11. Support the creation and sharing of informal design artefacts
Rationale: Many decisions are made and represented in notepads or post-it notes rather than within formal specification documents.
Priority: High

12. The tool should be compatible with existing work practices
Rationale: Software development teams have existing tools that this system will not replace. However the new system should be able to work alongside these.
Priority: High

13. Allow the end users to easily share their knowledge
Rationale: It is difficult for the users to find time to provide input into the software development process (particularly their domain knowledge). Therefore it should be easy for them to access and use the system.
Priority: Medium

14. The system should not enforce set processes on users
Rationale: Processes vary across projects
Priority: High

15. The system should not enforce set roles on users
Rationale: Roles vary across projects
Priority: High

16. Provide means for the design rationale to be converted into or used in the development of formal specifications

Rationale: Airbus requires the creation of formal software requirements documentation and system specifications. The system should feed into this process.
Priority: Medium

Non-functional requirements

17. The system should be responsive and quick to load.
    Rationale: Meetings often happen in an ad-hoc manner so it is important that system use can be initiated almost instantaneously. It should also support the fast moving nature of meetings.
    Priority: Medium

18. The system should reduce the amount of software that needs to be installed on machines
    Rationale: Employees do not always have permissions to install software on their machines
    Priority: Medium

19. Avoid the use of cloud based storage
    Rationale: Due to data security the company does not support the use of cloud based storage that may be insecure
    Priority: High

20. Do not require access to WiFi
    Rationale: The company premises do not have a WiFi network for general employee access.
    Priority: High

21. The system should be compatible with inputs and outputs of other systems.
    Rationale: The software development teams use a range of tools and are likely to continue to do so. Therefore the system should be compatible with these.
    Priority: High

Domain Requirements

22. Allow users to create complex representations such as diagrams, graphs, and algebraic notation
    Rationale: Aerodynamic design frequently involves these types of representation and they are often used when explaining and sharing domain knowledge.
    Priority: High

Additional Requirements From Workshop

23. Make capture of decisions as simple as possible (perhaps automatically)
24. Reduce barriers to system uptake
25. Support the ability to create formal documentation automatically or with as little effort as possible.
26. Support the creation of documentation for management purposes.
27. Allow requirements to be represented and communicated visually.

9.5.4 Technology Evaluation

Having established these requirements, the design workshop resulted in the selection of two potential technologies to be evaluated in situ. The evaluations with two stakeholders appeared to conclude that the Echo Smartpen could satisfy many of these (although it is not truly multi-purpose as teleconferences could not be recorded). It allows most meetings to be better recorded, ensuring that decisions are stored for later reference. In addition to this, unlike the tablet, it is easy to use and fits well into existing work practices. However, it should be noted that there are further technologies that could meet these requirements that these could be investigated in future work.

9.5.5 Case Study Summary

This case study has provided support for previous findings related to the characteristics of collaborative software development. It has looked at identifying requirements for technology to better support some of the challenges related to these characteristics. Finally evaluations of two potential solutions have been carried out and the Echo Smartpen was identified as the one with the most potential. It would therefore be interesting to study the use of the Echo Smartpen (or similar technology) in other software development contexts to see if it could also support this work in other domains.

9.6 Research Contributions

This chapter has summarised the work carried out in this thesis and how it answers the research questions set out. It has also attempted to highlight the contributions made by this. The following section will summarise these contributions more formally.

This thesis has provided a process and recommendations for establishing the 'needs' for support within a given context with a particular focus on collaborative needs. Importantly, it has shown how to feed the outputs from this into participatory design workshops that empowered stakeholders to match existing technology to the identified needs and high-level requirements.

The thesis has also presented a case study of software development teams at Airbus, identifying key characteristics and high level needs along with suggested requirements for any solutions. Consequently it has provided an evaluation of two potential technologies for meeting these needs.

9.6.1 Contributions to Research

A Process for Identifying Needs and Requirements

This research has presented a process and associated methods for identifying support 'needs' within an industrial setting with the specific focus on matching these to existing technology. This research contributes to the already extensive knowledge on the use of ethnography in design, especially within the fields of HCI and CSCW. However the focus of meeting needs with existing technology steps away from the more common use of informing the design of new technology.

A Method For Matching Needs to Existing Technology

This research has also described an extension of the PD method that involves stakeholders in identifying technology that could support their needs. This method encourages participants to creatively reimagine their work processes in the future and then looks at ways to achieve this with existing technology. The phases used in the workshop build on existing research into creative processes in PD and the use of scenarios in design but the process as a whole is novel. Additionally, the particular focus on the workshop as a follow on method for bridging the gap between ethnography and design is a novel application.

Introducing Technology

This work is of relevance to researchers or practitioners looking to carry out technological interventions, especially with existing technology. Individual, parts of this process, such as the design workshops, are also of interest in isolation as they could be adapted as a method in their own right.

Reflections on Methods in The Wild

Reflections on using these methods ‘in the wild' are also of interest to researchers carrying out studies in industry. A variety of techniques for data capture and analysis have been used and reflected on, with the conclusion being that informal ethnographic case studies yield better insights than more formal data collection and the use of theoretical frameworks.

Collaboration in Software Development

The case study of software development teams has provided further insight into the challenges of supporting collaboration within this context. Whilst this is an area that has been studied in depth (and this work has identified similar characteristics and recommendations) it is still an area of great interest as design and development processes continue to evolve. The case study particularly focuses on tools to aid traceability of decisions and the rationale behind them. Early discussions of this work were presented at the International Workshop on Cooperative and Human Aspects on Software Engineering (CHASE ’11) (Shipp & Johnson, 2011).

Studies of Design Rationale Capture

Through the small-scale studies of the pen and tablet at Airbus it has been possible to reflect on the success of these as prosthetic memory devices in the capture of design rationale. Findings from this could be used to inform the design and evaluation of future tools for capturing rationale in this way.

9.6.2 Contributions to Industrial Sponsor

This work has involved in depth studies of both aerodynamic engineers and software development teams at Airbus. The results of these case studies should be of interest to Airbus who can now use these to inform any future tool introduction. In addition to this, particular requirements for supporting collaboration in software development teams have been identified, as well as recommendations for technology that may meet these. These should be of direct relevance to Airbus who could introduce technology such as the Echo Livescribe Smartpen knowing that it may satisfy some of the collaborative needs of their software development teams.

By being involved with this research Airbus may consider the introduction of tools differently. Currently the focus is on supporting the more complex side of the work, but tools to support productivity and the collaborative aspects of work are also vital. The positive experiences of the two users who evaluated the Echo Smartpen provides support for this, however there are still challenges related to ensuring data security with these portable recording devices. The company may also chose to utilise the process and design workshop method outlined in this thesis when seeking to introduce any other technology in the future.

Technology Adoption

This thesis has explored the more practical issues associated with introducing technology, such as the barriers that may occur (in this case privacy and policy issues). It also recommends the consideration of the implications of appropriation on this process. Through evaluating existing technology in situ (prior to fully deploying it) a number of lessons can be learnt regarding the ways in which it is adopted into the working practices of the users and the organisational context as a whole. This can then inform future decisions about which technology to adopt, or where to make changes to ensure a more successful deployment.

9.7 Limitations

Whist this thesis has set out to present a detailed and thorough description of the research activities undertaken and the contributions that this has made, it is important to also highlight the limitations of this work.

Individual Researcher

A key feature of this process is that it has been carried out by a single researcher, yet this is not always the case in other contexts. Often it is necessary or even preferable to employ multiple ethnographers and field workers, as well as separate design and development teams. This brings a larger skill set to the process, but also places a strain on communication. For example, as has been highlighted in the literature, the richness of ethnographic findings may be lost when communicating it to designers or developers. Thus any potential issues that would arise here have not been tackled during this research.

Participant Numbers

Another feature of this research was the industry case study. Whilst this has brought validity to this work it has also limited some of the methods used. The recruitment of participants has been a specific problem, in particular during the technology evaluation and workshops. It is recognised that the reduced number of participants has impacted on the research outputs.

Continued Evaluation of Use

What this research hasn't been able to address is the study of technology use after this process has been carried out. As with many research projects, once the evaluation data is collected, the technologies are taken out of the context. Unfortunately this is not the desired output but was an inevitable part of the research. In an ideal world it would be possible to leave the selected technology (or a refined idea) within the company for further, long-term use. This would provide additional insights into the suitability of the technology and ways in which it has been appropriated.

9.8 Future Work

Refinement of the Process

This thesis has demonstrated the use of a process for eliciting system needs and matching these to existing technology. As has been mentioned, it has been developed and reflected on through a case study forming the focus of this thesis. The natural progression from this work would be to repeat and refine this process within other contexts. This may be a shorter more focused procedure as efficiencies can be made through the recommendations provided within this document, such as case study based ethnographic observations and design workshops.

Further SmartPen Evaluations

In addition to further exploration of the method, it would be interesting to consider a deeper investigation of the use of the Echo Smartpen at Airbus. Whilst the user evaluations provided an initial understanding of its use, there were limited instances of reflections regarding the ways in which it can support the capture and sharing of design rationale. As this was the main rationale behind its introduction it would be beneficial to carry out longitudinal studies of its use 'in the wild', perhaps focusing on specific case studies of its use within software development projects.

Exploration of the Workshop Method

Whilst the design workshops have been proposed as part of a larger design process, it would be interesting to pursue their use within a more 'quick and dirty' context. How could they be used without the prior ethnographic work, or perhaps following short periods of focused ethnographic studies? The use could also be extended beyond technological interventions, looking at demonstrating existing or novel processes and procedures that could be introduced into workplaces. It would also be interesting to look at alternative methods for defining an output from the workshops that can be carried out by the participants themselves. The current process relies on a period of analysis to determine the technology to move forward with. Future Workshops (Kensing, Halskov, & Madsen, 1991) focus on generating concrete courses of actions as an output from the workshops.

For example recent work by Muller, Geyer, Soule, Daniels, and Cheng (2013) has looked at crowdsourcing initiatives for gaining support and funding for technology projects within companies. This included employee proposed projects such as introducing 3D printers, or telepresence robots into labs (although suggestions also looked at moral boosting sports equipment). This method allows corporate approval processes to be bypassed, giving more power to employees to propose the introduction of technologies that may support their work. However it assumes that employees are aware of these technologies in the first place (the company in question was IBM). It would be interesting to combine this process with the design workshop where technologies are introduced to employees who can then build a case for their selected technology and then put it to the crowd funding 'jury' process to decide which should be implemented or perhaps initially trialled.

Studies of Design Rationale Retrieval

Whist the case study within this thesis has touched on the subject of rationale capture within software development, there are many further potential issues within this that should be researched in more detail. For example, retrieval of this rationale is a complex process. Within the studies of the pen and tablet, there were some doubts raised about whether the participants would have time to listen back to the audio of meetings in full. However, the Smartpen does allow for audio to be indexed in a manner that should allow more efficient retrieval. The studies discussed within 3.13 and 3.14 demonstrate some of the research carried out in the field of design rationale management and audio recording. However, there is also a body of research concerned specifically with retrieval of design rationale and future studies of technologies such as the Smartpen could contribute to this field.

Implications for Accountability

A further implication of this research that should be studied further is that of accountability in design. Previously (and this is still the case) the design teams at Airbus used their own notebooks to record design decisions informally, yet with the introduction of technologies such as Smartpens, discussions could be recorded fully and referred back to. Whilst this concept provides benefits in allowing design decisions to be revisited, these records could also be used for accountability purposes if anything was to later go wrong with the systems being developed. Therefore this is an area that should be explored, especially relating to the attitudes surrounding the introduction of systems like this.

Works Cited

Adams, A., & Cox, A. L. (2008). Questionnaires, in-depth interviews and focus groups. In P. Cairns, & A. L. Cox, *Research Methods for Human-Computer Interaction* (pp. 17-34). Cambridge: Cambridge University Press.

Adams, A., Lunt, P., & Cairns, P. (2008). A qualitative approach to HCI research. In P. Cairns, & A. L. Cox, *Research Methods for Human-Computer Interaction* (pp. 138-157). Cambridge: Cambridge University Press.

Airbus. (2013). *Airbus.com*. Retrieved Jan 21st, 2013 from The success story of Airbus: http://www.airbus.com/company/history/

Airbus. (2013). *Airbus.com*. Retrieved Jan 21st, 2013 from http://www.airbus.com/aircraftfamilies/passengeraircraft/a380family/

Airbus. (2013). *Airbus.com*. From http://www.airbus.com/aircraftfamilies/passengeraircraft/a320family/

Anderson, R. J. (1994). Representation and Requirements: The Value of Ethnography in Systems Design. *Human Computer Interaction , 9*, 151-182.

Atkinson, P., & Hammersley, M. (1994). Ethnography and Participant Observation. In *Handbook of Qualitative Research.*

Avison, D., & Fitzgerald, G. (1988). *Information Systems Development Methodologies, Technologies and Tools.* Oxford: Blackwell Scientific Publications.

Begel, A., Nagappan, N., Poile, C., & Layman, L. (2009). Coordination in Large-Scale Software Teams. *ICSE Workshop on Cooperative and Human Aspects of Software Engineering (CHASE '09).* IEEE.

Bellotti, V., & Smith, I. (2000). Informing the Design of an Information Management System with Iterative Fieldwork. *the 3rd Conference in Designing Interactive Systems: Processes, Practices, Methods, and Techniques (DIS '00)* (pp. 227 - 237). New York: ACM.

Beyer, H., & Holtzblatt, K. (1999, January). Contextual Design. *Interactions , 6* (1), pp. 32-42.

Blandford, A., Cox, A. L., & Cairns, P. (2008). Controlled Experiments. In P. Cairns, & A. L. Cox, *Research Methods for Human-Computer Interaction* (pp. 1-16). Cambridge: Cambridge University Press.

Boehm, B. (1988). A Spiral Model of Software Development and Enhancement. *IEEE Compter , 21* (5), 61-72.

Boehm, B. (1988, May). A Spiral Model of Software Development and Enhancement. *IEEE Computer* , pp. 61-72.

Boehm, B. (2006). Some Future Trends and Implications for Systems and Software Engineering Processes. *Systems Engineering , 9* (1), 2006.

Brown, T. (2009). *Change by Design.* Harper Collins.

Button, G. (2000). The Ethnographic Tradition and Design. *Design Studies , 21*, 319-332.

Button, G., & Dourish, P. (1996). Technomethodology: Paradoxes and Possibilities. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 19-26). New York: ACM.

Buur, J., & Matthews, B. (2008). Participatory Innovation: A Research Agenda. *Participatory Design (PDC '08)* (pp. 186-189). IN: Indiana University.

Cadle, Y., & Yates, D. (2004). *Project Management for Information Systems.* Essex: Pearson Education.

Cameron, E., & Green, M. (2012). *Making Sense of Change Management: A Complete Guide to the Models, Tools and Techniques of Organisational Change* (3rd Edition ed.). London, UK: Kogan Page Publishers.

Carroll, J. (2000). *Making Use; Scenario-Based Design of Human-Computer Interaction.* Cambridge, MA: MIT Press.

Carroll, J., Howard, S., Vetere, F., Peck, J., & Murphy, J. (2001). Identity, power and fragmentation in cyberspace: technology appropriation by young people. *Australian Conf. on Information Systems.*

Carter, S., & Mankoff, J. (2005). When participants do the capturing: the role of media in diary studies. *SIGHI Conference on Human Factors in Computing Systems (CHI '05)* (pp. 899-908). New York: ACM.

Checkland, P. (2000). Soft Systems Methodology: A Thirty Year Retrospective. *Systems Research and Behavioural Science , 17*, 11-58.

Cherns, A. (1976). The Principles of Sociotechnical Design. *Human Relations , 40*, 153-162.

Chilana, P. K., Ko, A. J., & Wobbrock, J. O. (2009). Designing Software for Unfamiliar Domains. *the 2009 ICSE Workshop on cooperative and Human Aspects of Software Engineering (CHASE '09)* (pp. 22-). Washington, DC: IEEE Computer Society.

Coffey, A., & Atkinson, P. (1996). *Making Sense of Qualitative Data: Complementary Research Strategies.* London, UK: SAGE Publications Ltd.

Conklin, J. (2005). Wicked Problems & Social Complexity. In J. Conklin, *Dialogue Mapping: Building Shared Understanding of Wicked Problems.* Wiley.

Crabtree, A. (2003). *Designing Collaborative Systems: A Practical Guide to Ethnography.* London: Springer.

Crabtree, A., Benford, S., Greenhalgh, C., Tennet, P., Chalmers, M., & Brown, B. (2006). Supporting Ethnographic Studies of Ubiquitous Computing in the Wild. *DIS.*

Crabtree, A., Chamberlain, A., Davies, M., Glover, K., Reeves, S., Rodden, T., et al. (2013). Doing Innovation in the Wild. *CHItaly 2013.* ACM.

Crabtree, A., Rouncefield, M., & Tolmie, P. (2012). *Doing Design Ethnography.* London: Springer.

Curtis, B., Krasner, H., & Iscoe, N. (1988, November). A Field Study of the Software Design Process for Large Systems. *Communications of the ACM , 31* (11), pp. 1268-1287.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User Acceptance of Computer Technology: A Comparison of Two Models. *35* (8), 982-1003.

Davis, F. (1989, Sept). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly , 13* (3).

Diehl, M., & Stroebe, W. (1987). Productivity Loss in Brainstorming Groups: Toward the Solution of a Riddle. *Journal of Personality and Social Psychology , 53*, 497-509.

Dix, A. (2007). Designing for Appropriation. *British CHI Group Annual Conference on People and Computers (BCS-HCI '07)* (pp. 27-30). Swindon: British Computer Society.

Dix, A., Finlay, J., Abowd, G. D., & Beale, R. (2004). *Human Computer Interaction* (3rd Edition ed.). Harlow, Essex: Pearson Education Limited.

Dourish, P. (2006). Implications for Design. *CHI.* New York: ACM.

Dutoit, A. H., McCall, R., Mistrik, I., & Paech, B. (2006). Rationale Management in Software Engineering: Concepts and Techniques. In *Rationale Management in Software Engineering* (pp. 1-48). Berlin: Springer.

Grudin, J. (1994). Eight Challenges for Developers. *Communications of the ACM , 37* (1).

Grudin, J. (1990). The computer reaches out: the historical continuity of interface design. *the SIGCHI Conference on Human Factors in Computing Systems (CHI '90)* (pp. 261-268). New York: ACM.

Grudin, J., & Grinter, R. E. (1995). Ethnography and Design. *Computer Supported Cooperative Work , 3*, 55-59.

Grudin, J., & Poltrock, S. (2012). Taxonomy and theory in computer supported cooperative work. In S. W. Kozlowski, *The Oxford handbook of organisational psychology* (pp. 1323-1348). New York: Oxford University Press.

Gutwin, C., Penner, R., & Schneider, K. (2004). Group Awareness in Distributed Software Development. *the 2004 ACM conference on Computer Supported Cooperative Work (CSCW '04)* (pp. 72-81). New York, NY: ACM.

Halskov, K., & Dalsgård, P. (2006). Inspiration Card Workshops. *6th conference on Designing Interactive Systems (DIS '06)* (pp. 2-11). NY: ACM.

Hammersley, M., & Atkinson, P. (2007). *Ethnography Principles in Practice.* (Third, Ed.) London and New York: Routledge.

Harrison, S., Tatar, D., & Sengers, P. (2007). The Three Paradigms of HCI. *Alt.Chi Proceedings of CHI 2007.* NY: ACM Press.

Hartmann, B., Morris, M. R., Benko, H., & Wilson, A. D. (2010). Pictionaire: supporting collaborative design work by integrating physical and digital artifacts. *the 2010 ACM Conference on Computer Supported Cooperative Work (Savannah, Georgia, USA, February 06 - 10, 2010). CSCW '10.* (pp. 421-424). New York: ACM.

Herbsleb, J. D., & Grinter, R. E. (1999, Sept/Oct). Architectures, Coordination, and Distance: Conway's Law and Beyond. *IEEE Software* , pp. 63-70.

Herbsleb, J. D., Mockus, A., Finholt, T. A., & Grinter, R. E. (2000). Distance, dependencies, and delay in a global collaboration. *the 2000ACM conference on Computer Suported Cooperative Work CSCW '00* (pp. 319 - 328). New York: ACM.

Hughes, J. A., Randall, D., & Shapiro, D. (1993). From Ethnographic Record to System Design: Some Experiences from the Field. *Computer Support Cooperative Work , 1*, 123-141.

Hughes, J., King, V., Rodden, T., & Anderson, H. (1994). Moving out from the Control Room: Ethnograhy in System Design. *CSCW* (pp. 429-439). New York: ACM.

Hughes, J., O'Brien, J., Rodden, T., & Rouncefield, M. (1997). Designing with Ethnography: A presentation Framework for Design. *Procs of DIS '97* (pp. 147-158). ACM.

Hughes, J., O'Brien, J., Rodden, T., Rouncefield, M., & Sommerville, I. (1995). Presenting ethnography in the requirements process. In M. Harrison, & P. Zave (Ed.), *Proceedings of RE'95* (pp. 27-34). York: IEEE Computer Society Press.
Hutchins, E. (1995). *Cognition in the Wild.* Cambridge, USA: MIT Press.

Jameson, A., Martinelli, L., Alonso, J., Vassberg, J. C., & Reuther, J. (2000). Simulation Based Aerodynamic Design. *IEEE Aerospace Conference.* Big Sky, Montana.

Johansen, R. (1988). *Groupware: Computer support for business teams.* New York: The Free Press.

Judge, T. K., Neustaedter, C., Tang, A., & Harrison, S. (2010). Bridging the Gap: Moving from Contextual Analysis to Design. *the 28th International Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '10)* (pp. 4497-4500). New York: ACM.

Jungk, R., & Müllert, N. (1987). Future workshops: How to create desirable futures London:. *Institute for Social Inventions* .

Kalnikaitė, V., & Whittaker, S. (2007). Software or Wetware? Discovering When and Why People Use Digitial Prosthetic Memory. *CHI 2007* (pp. 71-80). New York: ACM.

Kalnikaite, V., Ehlen, P., & Whittaker, S. (2012). Markup as you talk: Establishing effective memory cues while still contributing to a meeting. *CSCW '12* (pp. 349-358). NY: ACM.

Kaptelinin, V., & Nardi, B. A. (2006). *Acting With Technology. Activity Theory and Interaction Design.* Cambridge, MA, USA: MIT Press.

Kensing, F., Simonsen, J., & Bødker, K. (1996). MUST - a Method for Participatory Design. In F. K.-E. J. Blomberg (Ed.), *Proceedings of the Fourth Biennial Conference on Participatory Design* (pp. 129-140). Palo Alto: Computer Professionals for Social Responsibility.

Kensing, Halskov, & Madsen. (1991). Generating Visions: Future Workshops and Metaphorical Design. In J. Greenbaum, *Design at Work: Cooperative Design of Computer Systems.* NJ: Lawrence Erlbaum.

Kline, T. J. (2001). The Groupware Aoption Scale: a measure of employee acceptance. *Human Systems Management , 20*, 59-62.

Kraut, R. E., & Streeter, L. A. (1995, March). Coordination in Software Development. *Communications of the ACM , 38* (3), pp. 69 - 81.

Kuutti, K. (1996). Activity Theory as a Potential Framework for HCI Research. In B. A. Nardi, *Context and Consciousness: Activity Theory and Human-Computer Interaction* (pp. 17-44). Cambridge, MA, USA: MIT Press.

Lewin, K. (1952). Group Decision and Social Change. In E. Newcombe, & R. Harley, *Readings in Social Psychology* (pp. 459-473). New York: Henry Holt.

Luminant Software. (n.d.). Retrieved Feb 02, 2013 from http://luminantsoftware.com/iphone/audionote.html

Marois, L., Viallet, J., Poirier, F., & Chauvin, C. (2010). Experimenting Introductory Tools for Innovation and Participatory Design. *11th Biennial Participatory Design Conference (PDC '10)* (pp. 259-262). New York: ACM.

Martin, R., & Riel, J. (2010, March/April). Designing Interactions at Work: Applying Desing to Discussions, Meetings, and Relationships. *Interactions , XVII* (2).

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook.* London, UK: Sage Publications Ltd.

Muller, M. J., & Kuhn, S. (1993, June). Participatory Design. *Communications of ACM* , pp. 24-28.

Muller, M., Geyer, W., Soule, T., Daniels, S., & Cheng, L.-T. (2013). Crowdfunding inside the Enterprise: Employee-Initiatives for Innovation and Collaboration. *ACM SIGCHI Conference on Human Factors in Computing CHI'13* (pp. 503-512). New York: ACM.

Mumford, E. (1997). The reality of participatory systems design: contributing to stability in a rocking boat. *Information Systems Journal , 7* (4).

Nardi, B. A. (1996). Activity Theory and Human-Computer Interaction. In B. A. Nardi, *Context and Consciousness: Activity Theory and Human-Computer Interaction* (pp. 4-8). Cambridge, MA, USA: MIT Press.

Nardi, B. A. (1996). Studying Context: A Comparison of Activity Theory, Situated Action Models, and Distributed Cognition. In B. A. Nardi, *Context and Consciousness: Activity Theory and Human-Computer Interaction* (pp. 35-52). Cambridge, USA: MIT Press.

Nathan, M., Topkara, M., Lai, J., Pam, S., Wood, S., Boston, J., et al. (2012). In Case You Missed It: Benefits of Attendee-Shared Annotations for Non-Attendees of Remote Meetings. *CSCW 2012.* New York: ACM.

Norman, D. (2010, March/April). Technology First, Needs Last: The Research-Product Gulf. *Interactions , XVII* (2).

Nye, D. (2006). *Technology Matters: Questions to Live With.* Cambridge, MA: MIT Press.

Olsen, W. K. (2004). Triangulation in Social Research: Qualitative and Quantitative Methods Can Really Be Mixed. In M. Holborn, & M. Haralambos, *Developments in Sociology.* Causeway Press.

Olson, G. M., & Olson, J. S. (2000). Distance Matters. *Human Computer Interaction , 15* (2), 139-178.

Olson, G. M., Olson, J. S., Carter, M. R., & Storrøsten, M. (1992). Small group design meetings: an analysis of collaboration. *Human Computer Interaction , 7* (4), 347-374.

Olson, J. S., & Teasley, S. (1996). Groupware in the wild: lessons learned from a year of virtual collocation. *the 1996 ACM conference on Computer supported cooperative work (CSCW '96)* (pp. 419-427). New York: ACM.

Orlikowski, W. J. (1992). Learning from Notes: Organisational Issues in Groupware Implementation. *the 1992 ACM Conference in Computer-Supported Cooperative Work (CSCW '92)* (pp. 362-369). New York: ACM.

Orlikowski, W. J., & Hofman, J. D. (1997). An Improvisational Model of Change Management: The Case of Groupware Technologies. *Sloan Management Review , 38* (2), 11-21.

Paton, R. A., & McCalman, J. (2008). *Change Management: A guide to effective implementation.* Sage.

Piaget, J. (1932). *The moral judgment of the child. London:.* London: Routledge & Kegan Paul.

Pilone, D., & Miles, R. (2008). *Head First Software Development.* O'Reilly Media.

Preece, J., Rogers, Y., & Sharp, H. (2002). *Interaction Design: Beyond Human Computer Interaction.* New York: John Wiley & Sons, Inc.

Regli, W. C., Hu, X., Atwood, M., & Sun, W. (2000). A Survey of Design Rationale Systems: Approaches, Representation, Capture, and Retrieval. *Engineering with Computers , 16*, 209-235.

Resnick, M. (2007). All I really need to know (about creative thinking) I learned (by sudying how children learn) in kindergarten. *6th ACM SIGCHI conference on Creativity and Cognition* (pp. 1-6). New York: ACM.

Rogers, Y. (1994). Exploring Obstacles: Integrating CSCW in Evolving Organisations. *the 1994 ACM Conference on Computer Supported Cooperative Work (CSCW '94)* (pp. 67-77). New York: ACM.

Rogers, Y. (2011, July + August). Interaction Design Gone Wild: Striving for Wild Theory. *Interactions* , pp. 58-62.

Rosson, M. B., & Carrol, J. M. (2002). *Usability Engineering: Scenario-Based Development of Human-Computer Interaction.* San Francisco: Morgan Kaufmann Publishers.

Salovaara, A., Höök, K., Cheverst, K., Twidale, M., Chalmers, M., & Sas, C. (2011). Appropriation and creative use: linking user studies to design. *the 2011 annual conference extended abstracts on Human factors in computing systems (CHI EA '11)* (pp. 37-40). New York: ACM.

Schröter, A., Aranda, J., Damian, D., & Kwan, I. (2012). To Talk or Not to Talk: Factors that Incluence Communication around Changesets. *Proceedings of 2012 ACM Conference on Computer Supported Cooperative Work (CSCW 2012).* Seattle: ACM.

Sharp, H. (1991). The Role of Knowledge in Software Design. *Behaviour & Information Technology , 10* (5), 383-401.

Sheehan, K. B. (2001). E-mail: Survey Response Rates: A Review. *Journal of Computer-Mediated Communication , 6* (2).

Shevell, R. (1989). *Fundamentals of Flight.* Pearson Education.

Shipp, V., & Johnson, P. (2011). Collaboration in the Development on Complex Engineering Software. *the 2011 Workshop on Cooperative and Human Aspects on Software Engineering (CHASE '11).* New York: ACM.

Simonsen, J., & Kensing, F. (1997, July). Using Ethnography in Contextual Design. *Communications of the ACM , 40* (7), pp. 82-88.

Sommerville, I. (2001). *Software Engineering.* Essex, UK: Pearson Education Ltd.

Sommerville, I., Rodden, T., Sawyer, P., Bentley, R., & Twidale, M. (1992). Integrating Ethnography into the Requirements Engineering Process. In S. F. Finkelstein (Ed.), *IEEE International Symposium on Requirements Engineering* (pp. 165-173). Los Alamitos, CA: IEEE Computer Society Press.

Sommerville, I., Sawyer, P., & Viller, S. (1998). Viewpoints for requirements elicitation: a practical approach. *Proceedings of ICRE'98* (pp. 341-353). IEEE Computer Soc. Press.

Stifelman, L., Arons, B., & Schmandt, C. (2001). The audio notebook: paper and pen interaction with structured speech. *CHI '01* (pp. 182-189). NY: ACM.

Suchman, L. A. (1987). *Plans and Situated Actions. The problem of human and machine communication.* Cambridge: Cambridge University Press.

Suchman, L. (2002). Practice-Based Design of Information Systems: Notes from the Hyperdeveloped World. *The Information Society: An International Journal , 18* (2), 139-144.

Viller, S., & Sommerville, I. (1999). Coherence: An Approach to Representing Ethnographic Analyses in Systems Design. *Human-Computer Interaction , 14* (1-2).

Viller, S., & Sommerville, I. (1999). Social analysis in the requirements engineering process: from ethnography to method. *Proceedings of the IEEE International Symposium on Requirements Engineering, 1999* (pp. 6-13). IEEE.

Whittaker, S., Hyland, P., & Wiley, M. (1994). Filochat: Handwritten Notes Provide Access to Recorded Conversations. *CHI 1994* (pp. 271-277). New York: ACM.

Yin, R. K. (2009). *Case Study research: Design and Methods* (4th ed.). London: SAGE Ltd.

Yu, S.-J., & Selker, T. (2010). Who Said What When? Capturing the Important Moments of a Meeting. *CHI Extended Abstracts* (pp. 3283-3288). NY: ACM.

Appendices

Appendix A

Collaborative Software Development Survey

This survey is designed to gather information about your experiences of developing software as part of a team and should take no more than **15 minutes** to complete. Please could you answer the questions below in as much detail as possible.

By submitting this questionnaire you are providing consent for your responses to be analysed and used in my research. You may omit any items on the questionnaire that you prefer not to answer. Any discussion of the data will be completely anonymous and you have the right to withdraw your consent at any time.

1. Where is your primary place of work (i.e. Filton, SDC, Toulouse etc).

2. Please explain your role within the development process.

3. Using the scale below, please indicate how much you agree or disagree with the following statement:

'The development team are able to work well together to produce successful software systems'

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Please explain your reasons for this response.

4. Using the scale below, please indicate how much you agree or disagree with the following statement:

'The mechanisms for supporting team work are successful'

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Please explain your reasons for this response.

5. What tools and processes do the team use to build a common understanding of the software being developed and how successful are these?

6. Are there ever misunderstandings or miscommunications between the team? If so, why do you think these happen?

7. What role do the end users play in the development process?

8. Do you feel that being aware of the activities of the rest of the team is important to your work, and is your current level of awareness sufficient?

9. What role does informal, unplanned communication play in the development process and how does this usually occur (i.e. face-to-face, email etc)?

10. What is your preferred way of communicating with the rest of the team? Please explain your reasons behind this.

11. What aspects of the development process do you feel work well? Please provide an illustrative example.

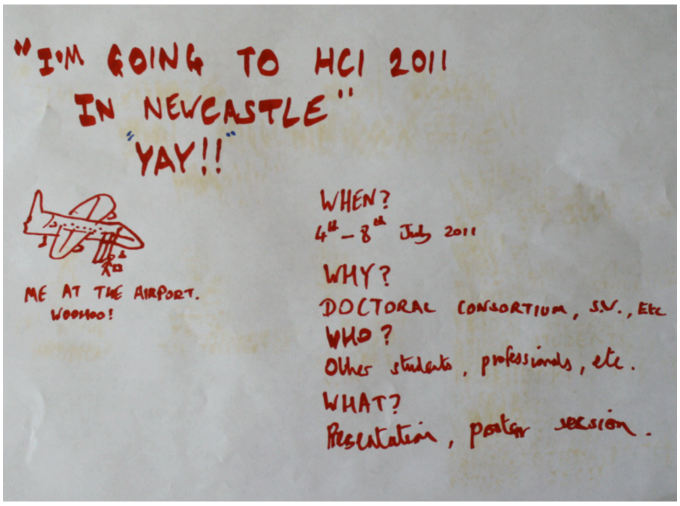
12. What aspects of the development process, if any, do you feel do not work well? Please provide an illustrative example.

Appendix B

Scenarios Workshop 1

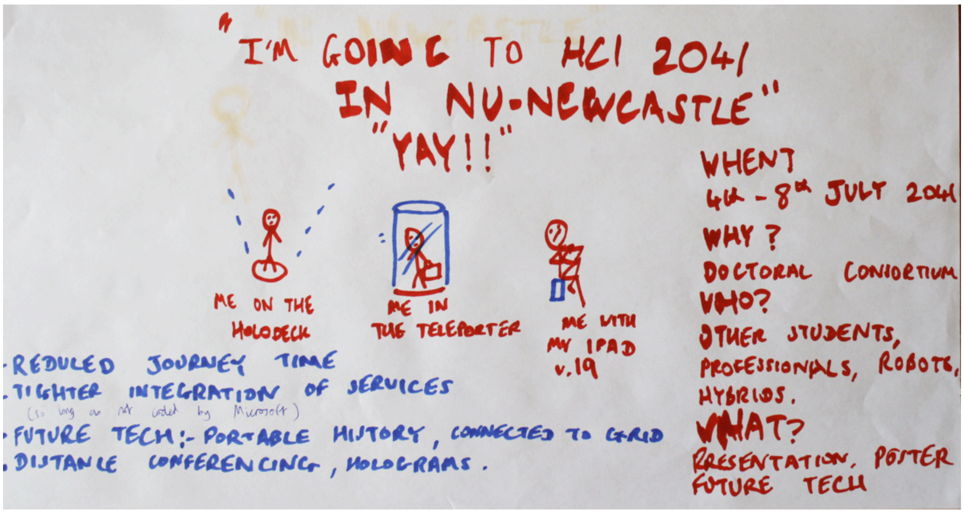
R Scenario One

"I'm going to a conference in Newcastle. I'm going to be there and other people that I haven't met yet...and [my supervisor] is going as well actually. And they'll be a poster session and I have to SV some of the sessions."



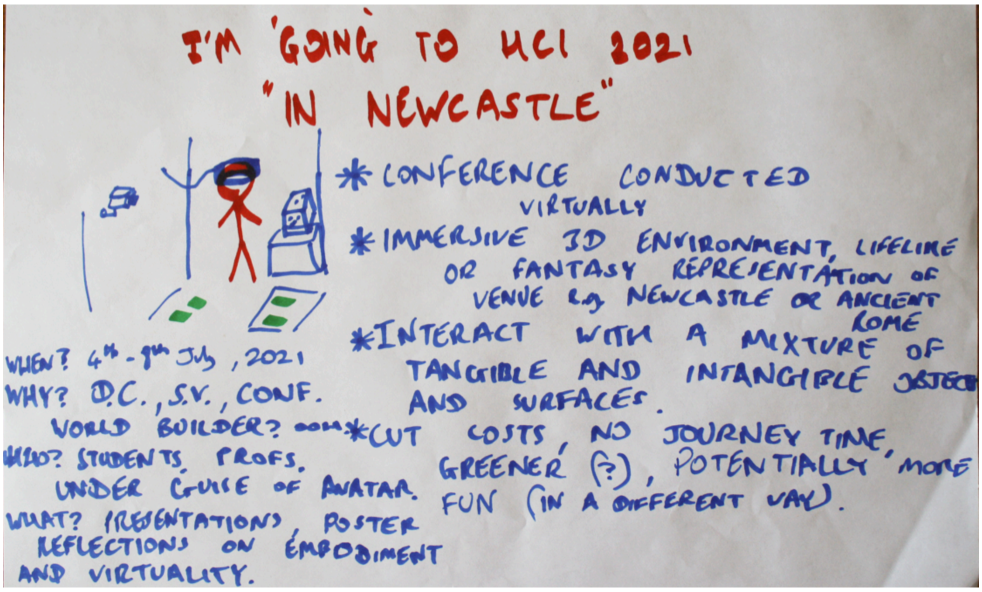
R Scenario Two – The Future

"I'm going to HCI 2041 in New Newcastle….and that's me having a significantly reduced journey time because I'm in a teleporter. That's me with an iPad cos you know iPads will be retro then. Everything else is the same except they'll be robots and hybrids at the conference and they'll be presentations of future tech cos we'll be so tech hungry then."



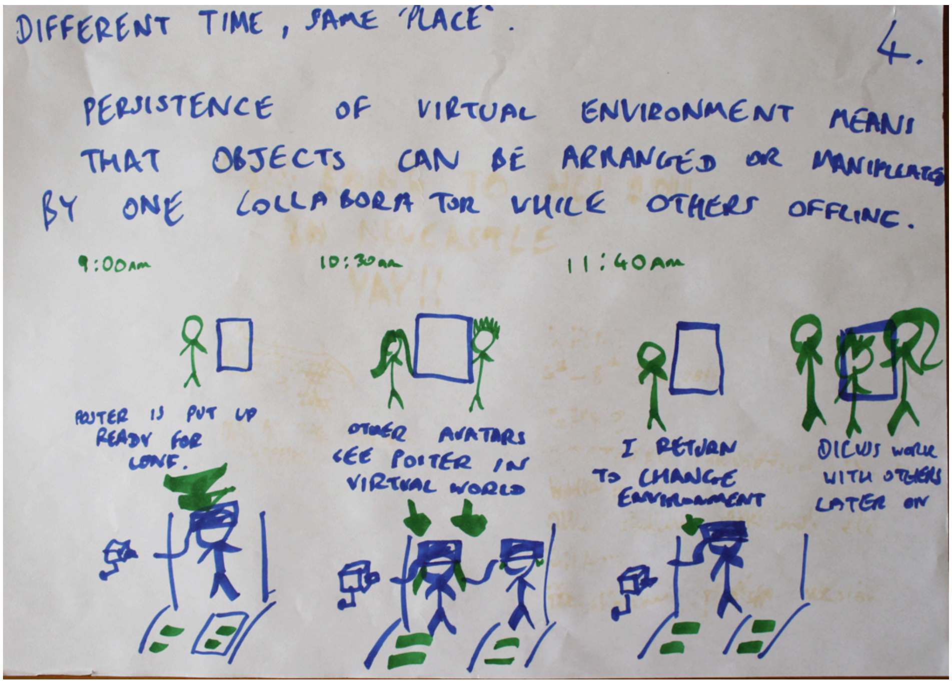
R Scenario Three – Technology Inspired

"It's a 3D virtual environment where the conference centre could be the real thing or it could be something else....the only difference is that everyone is under the guise of an avatar...We've got this technology but it's not this good....in 10 years it might be useful enough to actually do this."



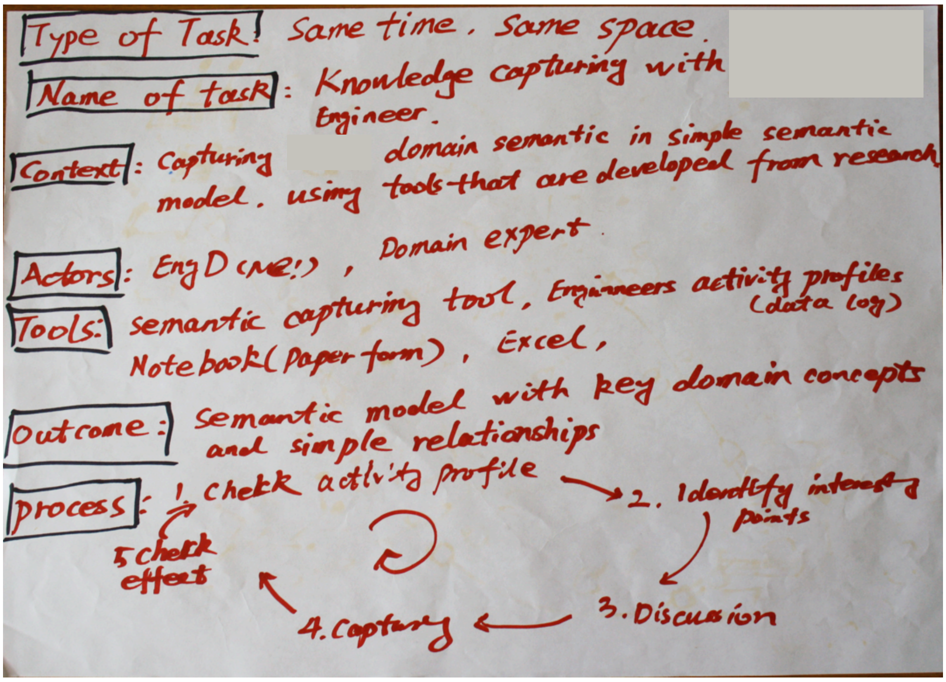
R Scenario Four – Different Context

"I'm using the technology in the same place but at a different time because the virtual environment is persistent I can log in and out...change things when people aren't there...I can go back later and talk to them..."



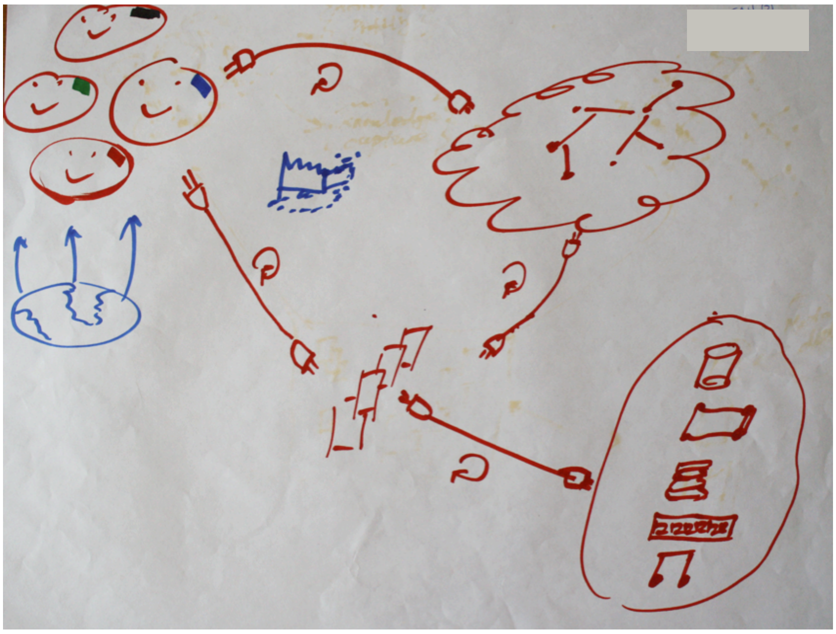
Y Scenario One

"Type of task is same time/same space. Name of the task is knowledge capturing. The context is to capture specific domain knowledge in a simple semantic model using tools developed by guys in [EngD sponsor company] who are experts in area. Tools that are used are semantic capturing tools that have been developed. Engineers activity profile where basically we capture the users use of the system. It's an excel based spreadsheet….So other tools are notebook and pen, excel. The outcome is a semantic model with key domain concepts….We will look at the activity profile first, identify something that's interesting, we have a discussion between me and the experts. We see if this one is interesting, it's useful but why is it useful. We capture it if it's useful and then we try to develop the impact of the model…."



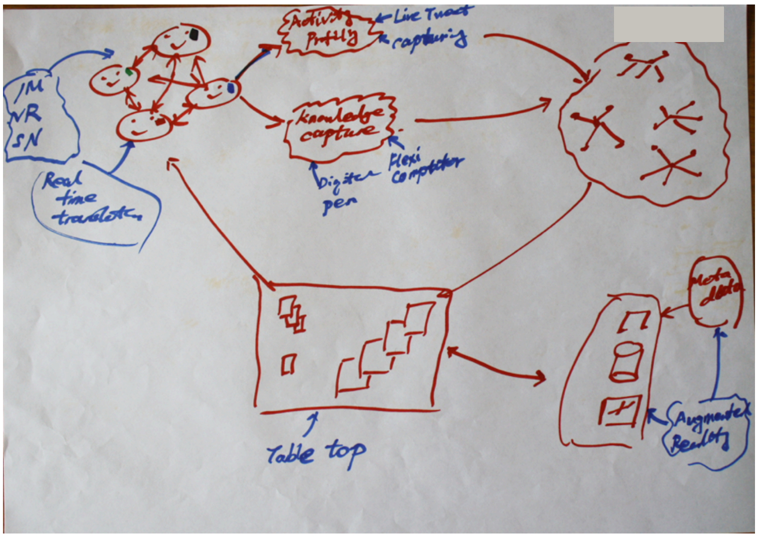
Y Scenario Two – The Future

"So erm the vision of 20 years that means no more office, people from all over the world, different type of people….Essentially what we're talking about in my line of work is knowledge capturing. And we want to capture knowledge as efficiently and automatically as possible, and less disturbing for people. You want to take what people have and interpret it in the computer world into a model, and the model would be able to consolidate this different thinking into a concrete artefact of information. But this kind of information also comes from different kind of media so database, that could be Chinese scroll old scroll, books….and automatically present it back to people, delivering information at the right time to the right people in the right context, that's the holy grail."



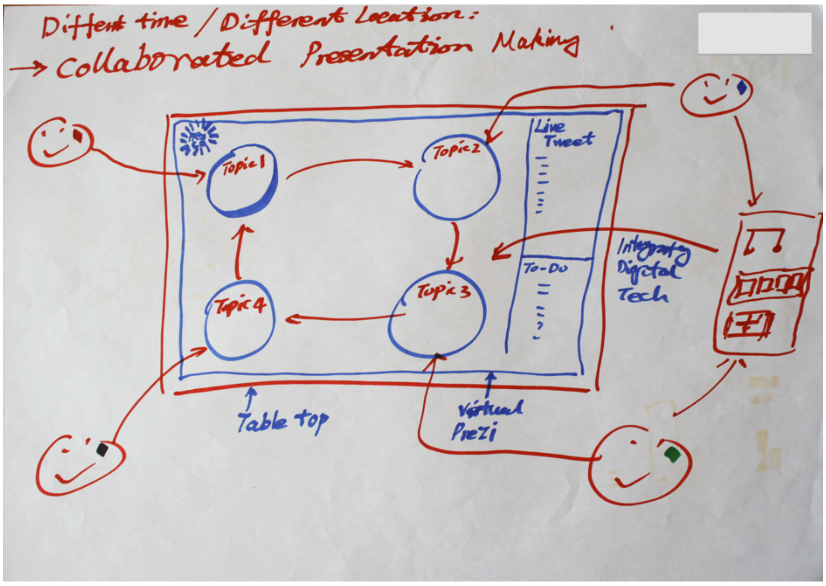
Y Scenario Three – Technology Inspired

"The main thing is to take the idea from some of these to put it into our existing process of capturing knowledge…..This is about 10 years in time. So we have a much more globalised working environment. People, shall we say, are interconnected…Virtual Reality like in second life…the Virtual Reality Office. Social networking and … semantic web and things like that. And also real time translation and that should be achievable in 5 years time actually…Using stuff like digital pen… basically replacing the physical notebook I'm using, better information capturing, better decision rationale capture, but at the same time trying to capture the engineers activity live by allowing Tweeting, email, automatic capturing of specific activities and by doing this we try to capture multiple models of individual users rather than a model for a group of users which is where we are at the moment"



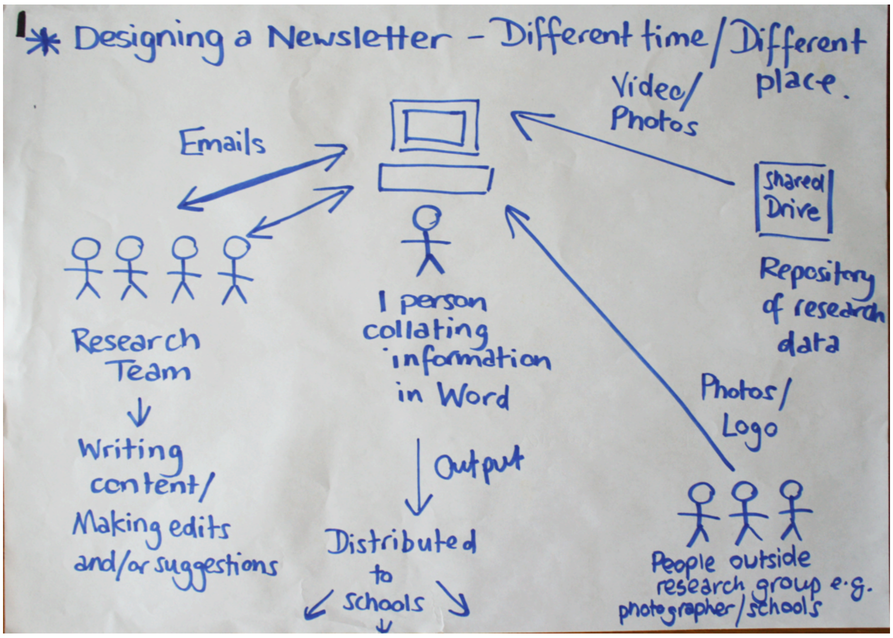
Y Scenario Four – Different Context

"This time is different time, different locations and the kind of task that I decided to go for is a collaborative presentation. Has anyone heard of Prezi, it's a presentation tool (explains Prezi). So you basically have the whole Prezi in a big picture, in a big canvas in a tabletop on different tabletops in different locations of the world and different collaborators working on it....Somehow they are all connected. Then on the side you would have the live Tweeting, or the live activity profile to see who is doing what at a certain stage. To do this people can look at it and say 'that's done' etc. Again you have the stuff in digital information which is stored and located on different devices but you can seamlessly drag and drop form one location into the table top....An interactive way to create a presentation."



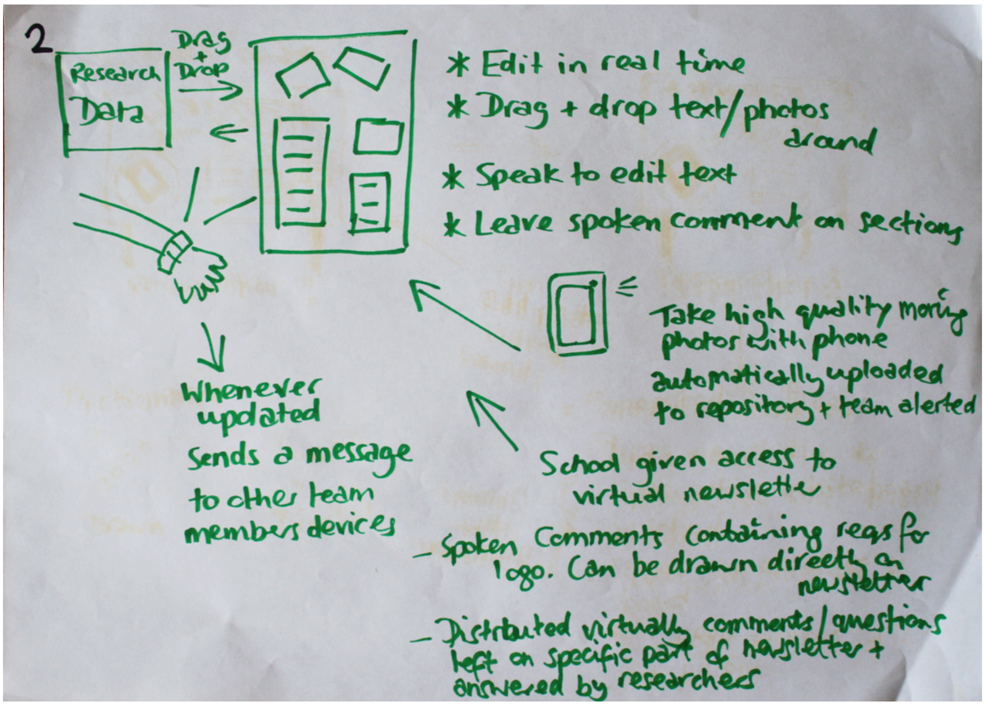
L Scenario One

"At the moment we're designing a newsletter to send out to schools that we work with just to give them an update on the project and we are saying what we are planning on doing after the summer holidays so we just want to send it out to parents of the kids that we're working with and the teachers as well to know what we're doing. So there are five of us in the research team that are doing it. I'm sort of putting it all together. So we've got four different people writing content and sending it via email to me and everyone else as well and then people commenting on that and then I'll put it all together and then we'll put it in a word doc and then that'll be sent back and forth and the research team will make some suggestions and then there's also other inputs....And we want to include some photos and things like that of what we've done... And also we're going to get one of the kids to design the logo for it as well. And then the output will be distributed to all the schools."



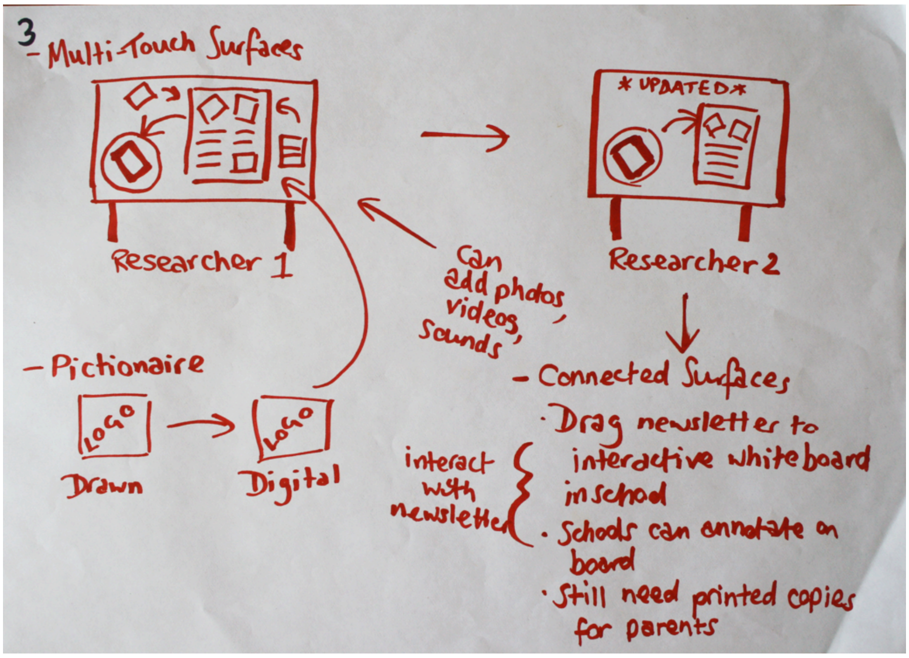
L Scenario Two – The Future

"So in my future everyone will wear magic watches which will project out the newsletter so you can, basically everyone can edit it in real time so no more emailing back and forth and getting confused as to which copy…if you want to type everything you just speak and it will edit the text automatically and also you can leave your comments and suggestions on sections for people to listen to. When it's updating everyone gets a message saying it's been updated and they can go in and see what's been done. And also they'd have like be able to directly access the research data and drag it all across. And then you'd be able to automatically take photos and that would be updated straight away into the repository and you'd give schools access to the newsletter so you'd have…our requirements for the logo you'd be able to leave that and add it on in the space it's supposed to be added. Then you could distribute it virtually as well and parents could add comments and again it would be left there. There's not this whole email exchange stuff."



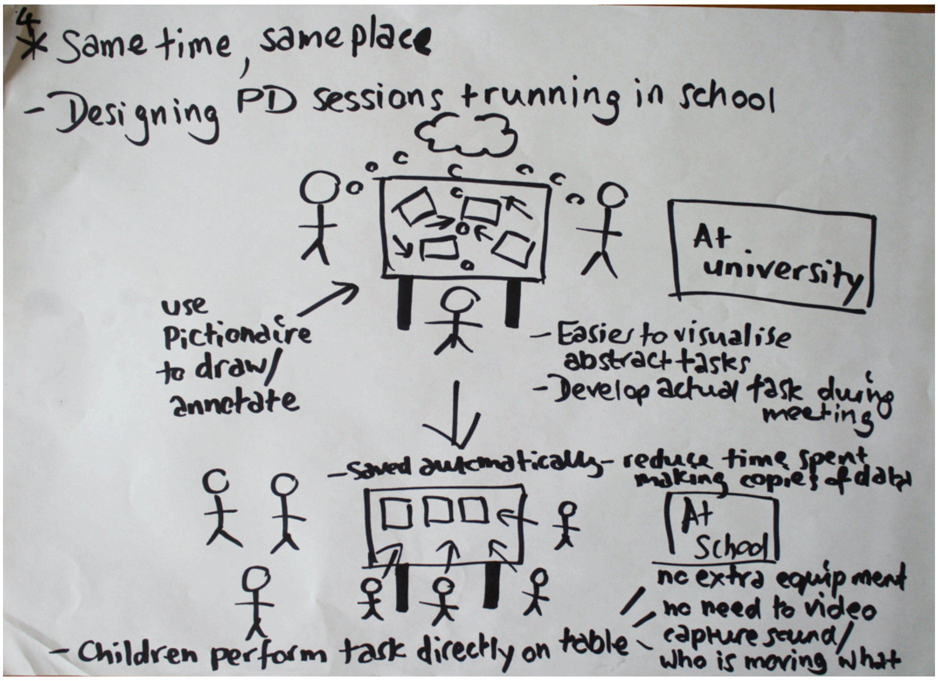
L Scenario Three – Technology Inspired

"Here I'm using the multi-touch surfaces…Drag it and share it via mobile phone…In terms of the logo using the Pictionaire thing, they could draw it and turn it fairly easily into the digital version of it. Then it could be shared with the school and so using the connected surfaces like dragging it up onto the whiteboard so the kids can see. So it's more of an interactive experience…but still at this stage you'd need to have printed copies for the parents. It's not, you cant use that tech because they don't have…you can put it in the schools but if people don't have the right technology you can't share it."



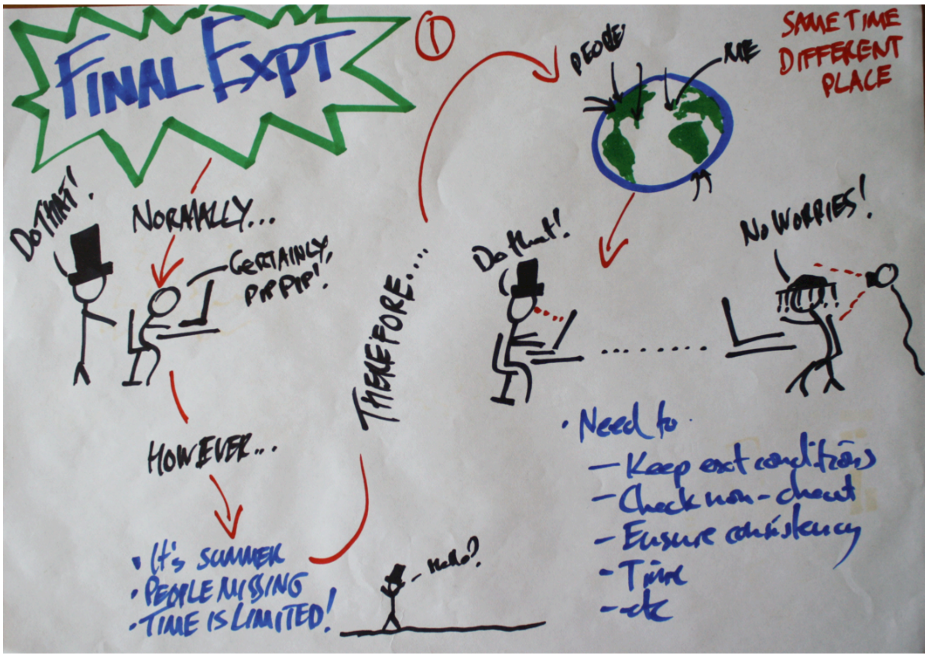
L Scenario Four – Different Context

"So I'm still using the multi-touch surface thing but this time using same time same place so I was thinking as I was doing it, 'oh this would be really good'! So all the people in the research team would all use it during the meeting like often you have to design tasks to do with the kids in school but its all very like just talking about it so it would be much better if we just actually build it as we went along on the table…..It also saves time you don't have to do it afterwards, you all do it at the same time. Then you can take that into the school and the kids can do the task on the multi-touch surface. It could help with filming too as it could automatically detect which child was moving and also like well I assume it could capture sound as well and then you've just got it all saved there and you haven't got all these bits of paper that you're got to try and store or digitise."



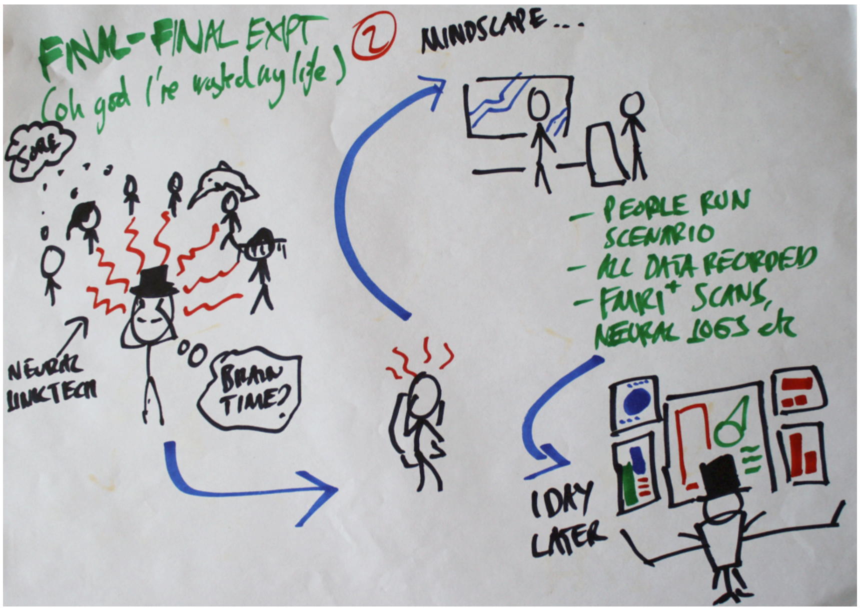
T Scenario One

"So this is about me running my final experiment. You can see I am wearing a top hat as I had to depict myself in the picture. And I'm telling someone to do something, and they're saying 'certainly, pip pip' because they are a British person. However it's summer and people are limited and I want to get on so….I do happen to know people around the world in different locations like America and Australia which aren't particularly convenient in terms of location…but with the miracle of technology I can sit at a computer here and I can see what they are doing via a webcam that will be positioned behind them and I'm saying 'do that' and this person is saying 'no worries' because they are Australian. I need to be cable to check for distractions which is why the camera is behind them so I can observe them from a distance."



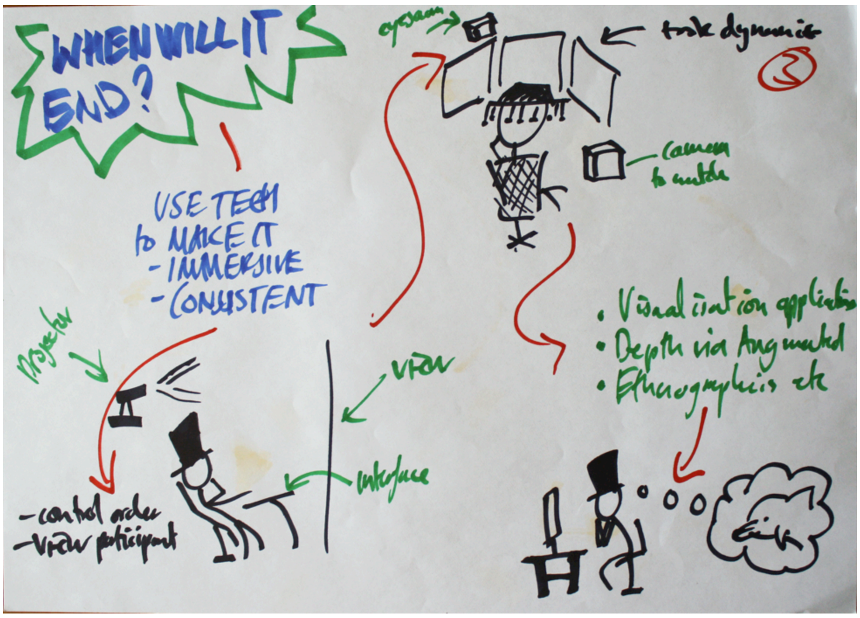
T Scenario Two – The Future

"So again this is my final experiment in 40 years time! My main thought is that we would have approached something along the lines of what (unclear) proposed as a singularity, i.e. approached the point when we can directly communicate with the technology around ourselves by a neural interface. Not unlike something from the Matrix ... In this case I would essentially just send out over this neural linked tech, something to anybody that I had a connection with. 'Can I borrow your brain for like 30 minutes'. ... Wherever they were they would just sit down for a bit and run through my mindscape a problem in the same way that I would give them a problem now. It's still along the lines of there are things that I want them to address but it would be a far more naturalistic setting. They would feel like they were actually there, they would be interacting with things and at this point everything would be being recorded, every neurological facet we can understand is being recorded. There'd be MRL scans, you know, direct neural real time imaging, logs of like individual activity etc. So not only that but I've just contacted a thousand people at once and I managed to get 600 of them to do my experiment and 1 day later ... I have the most data you could ever imagine to do whatever I want with and I'm just sitting at this amazing computer going through it all, pulling it statistical trends etc. So basically in the future I would be able to do my final experiment very very quickly."



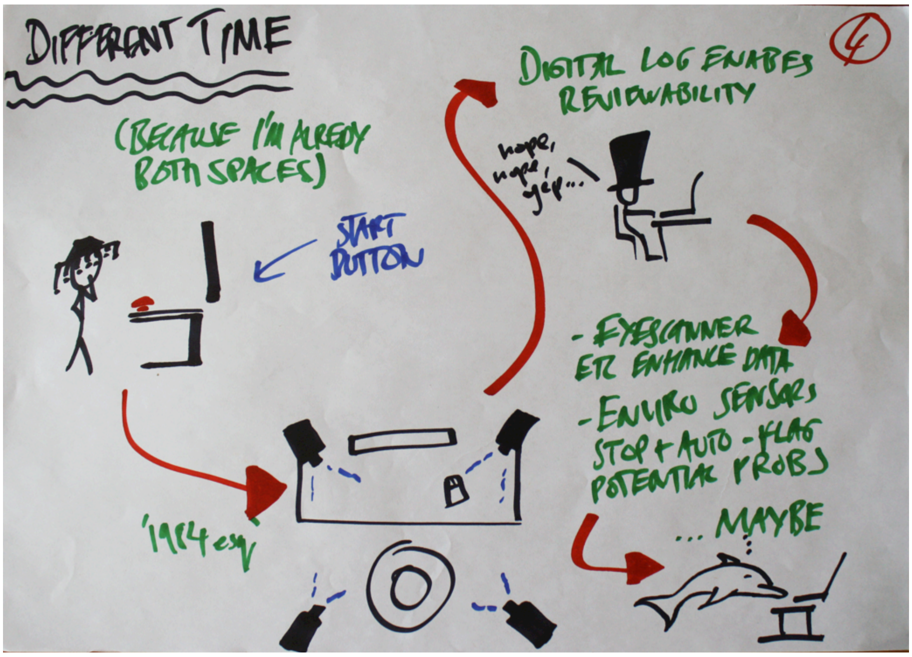
T Scenario Three – Technology Inspired

"The idea would be to use available technology to make things more immersive…so in this case I've given myself one of those mini projectors because I thought they were awesome machines, plus I could do it on a massive wall…so I could see how they're interacting no matter how far away they are. And I'd have like a drag and drop interface so I could direct what they're doing and start things. Again cos it's kind of cool and I'd like to have it … They'd have a touch screen, again not because it really changes the task but because it makes it a bit more immersive and a bit more ecologically valid, there's a bit more to it, they feel more involved in the decisions they're making. I've also added an eye scanner because you've got this new technology that can follow gaze direction even when the heads move and stuff…. And you have a camera behind so I can see what they're doing."



T Scenario Four – Different Context

"Because my last was both same and different place, that's already solved so it had to be different time. So the idea being that someone could just wander up to this set up and push a start button and do the whole thing and run the experiment. So obviously you'd need a 1984esque set up. You'd need more cameras and you'd need to record more stuff and I think you'd have more stuff like environmental sensors and stuff like that....The monitoring would enable the system to correct stuff...You'd still have some of the benefits, enhanced scanners, and you'd have enhanced data etc to make recordings and you'd actually be able to do it in such a way that's you'd be able to sustain the same level of consistency between the two things, regardless of whether I was there or wasn't there."



Workshop 3 Group Discussion (in full)

A: To be fair, I think some combination of that and that. So where you have a wall with a table on it and the table is one of those funky tables where you can physically move.
P: A surface that you can touch.
A: So there's a vertical surface which you can see the other people so you're getting the physical feedback from the other side and then there's a sort of 'manipulatable' virtual surface coming out the wall. So rather than just a flat table it's actually one of these funky surface things and you can flick things to people.
(drawing)
A: This is basically a big TV wall and it has multi-touch tables, which looks circular but is only half circular...You can do stuff on the table and flick it to the other side.
Facilitator: Could that be used in all the scenarios..?
C: Not in my case because I dunno what's happening in the tools, in the design team, this is not that usable.

A: But you could have it on there and then you could drag it up on the wall. There are like panels. So it's like a glass thing that you can stick onto the screen like a presentation.
F: It's a video wall…
A: It's a video wall and a screen. You can also drag things onto it.
C: That would be shared by?
A: Shared on both sides.
C: Shared. I told you…maybe a with the design team. Can I see what they're doing?
A: There is a feed. So even if you're not in this physical room you can still see what's on the table or the wall.
C: Because what you are talking about is a meeting. I may be person doing the meeting knowing what's the state of (unclear) so they want…they updated their landing gear you know. There is something important going on. It might not be a meeting, I'm walking, I'm having coffee, I see what's going on there. Ok. This could be really useful.
A: You see rather than having this normal meeting wall, have it in more of a social area.
C: Yes exactly. Either it can be used for a meeting, but having a social area you can see what's happening from a thinking point of view (unclear). Ok I would be interested in knowing….the flow of information, what's going on. This would allow to understand the big picture, what I'm doing…this is what I mean. Sometimes I am doing this, but now what I am doing with this, why this guy is doing that. If you go to Airbus and ask a wing design engineer, ok I am doing this because of this. Then you know who they need to give the data to but they don't know after what happened. It would be interested to see the big picture on a wall, not only during a meeting.
A: So a flexible wall where you can put up feeds or whatever.
(F asking if they could use it in all the contexts of the matrix)
A: So you can manipulate on the table. Same time different place, that's where the back wall comes in.
P: And then the different types like C was talking about, being able to access, basically a very elaborate noticeboard of what information relevant to you about the broader.
A: Wouldn't it be cool if detecting your phone in your pocket you walk up and it filters the feeds to you. Or for all the people in the coffee area. It knows the people who are there and only show the relevant information.
A: It doesn't have to be connected to anything on the other side (so can still be used in the same place at the same time).
A: Dif time, same place, that's what we have just said.
F: What about mobile use? If you couldn't be there.
A: If the artefacts are digital, on the table, on the wall, you want them in a different form so that you can see them on a small screen. But if they're digital artefacts you can kind of transform them to how you want them to be.

Appendix C

A First Interview -> Xoom

I	Get a feel for how you used it and what you thought. Do you have anything you want to say first.?
A	I can explain to you how I used it. The ain thing I used it for was taking it to meetings with the developers. I tried to use it as a laptop. Just take notes as you would. I also wanted to use the recording function but I didn't. First of all I don't think it would make sense to record the whole thing. I just wanted to record stuff that I wanted. It would be very fiddly to record/stop/record/stop. But if I did want to use it I would use it in that way. I would record the stuff..for example someone explaining something which is recorded. Something I wanted to ask though…you do need permission in a meeting to start recording?
I	Yes I always get permission from people because I know that..well ethically you need to get permission from people. So did you tell people you were recording or…?
A	Er no (laughs).
I	Do you think it would be an issue to say…Do you think people would say no if you asked?
A	They would in some cases definitely.
I	I'm trying to get a feel for how would it work in industry. Are there issues with it or can you just bring them in or use them today or things like that.
A	No..in industry, if you have, if you are discussing a project or a product it is very likely that it would get vetoed and they wouldn't allow you to record…But if you're conducting the meeting yourself, say I want to explain something, then I can I can say ok if you wouldn't mind…
I	And you could just record short bits perhaps so (explaining about recording for my research and not taking it off site). So do you think the recording would be useful?
A	…I mean the recording on the pen is much easier.
I	So you mainly used it in meetings. Did you use it any other times? Like when you were working on your own or anything?
A	Yes, so the feature I like, but it's not mature enough, but if it was it's something I would definitely use….is draw er engineering drawings. And write equations down, recorded immediately and communicated to people. Now the problem with this one is when you want to write things it's too thick. You can't use it. I would want a thin pen which I can write loads of things with, or I want to draw or something, maybe a picture of a wing, or some equations here and some explanation. I want it to all be on one sheet.
I	So you'd want a pen you can use on it.
A	A stylus.
I	I did buy a stylus.
A	Oh you can use a stylus?
I	(explaining about the stylus)

A	I tried with a pen, but I didn't want to break the screen.
I	(more stylus explanation)
A	I mean you could imagine how it would work, say I'm in a meeting and I'm trying or someone's explaining to me or I'm trying to explain to them. I could very quickly do a drawing and you can put some equations on it, take a .png, distribute it and perhaps I could use it in a presentation later. So it would be a very useful function, yes.
I	Which apps did you use mostly?
A	The notepad.
I	And did you use your email and things from it?
A	Yes, I sent one email. I was testing it. Then I came back and wrote it in my presentation. But the problem I have is I couldn't get used to the touchscreen typing. So there were usually a lot of mistakes.
I	So you transferred it to your laptop and typed it in?
A	Yes.
I	So rather than writing off a notepad into your computer you just typed from the tablet?
A	If I was comfortable with the typing on it then I think I would just email the whole thing.
I	And did you ever plug it into your PC or did you just..
A	No.
I	How easy did you find it to learn how to use it?
A	Yes it was easy.
I	I think I may have already covered this but you mainly used it for yourself for personal work? Rather than collaborative work as I would call it.
A	Yes.
I	Do you think it has potential for sharing things or do you think it would be more like a personal tool that you used.
A	Both to be honest. I can see the benefits of doing some collaborative work. Of course not developing anything on it, but things like exchanging ideas, pictures, notes. It could be a good collaborative tool.
I	Did you ever refer back to things you had created on it to remind you of things you'd discussed in meetings…
A	I looked at the notes.
I	Was that different to looking back at your notepad in anyway?
A	No.
I	So it was kind of the equivalent of having it as a notepad? Ok.
I	Did it meet your expectations? Was it any better or worse than you had expected?
A	I expected it to be a bit better.
I	Would you have liked to have used it for longer? Can you see yourself using this in the workplace?
A	As (unclear) sense. No. There are some things that are quite annoying. Like the screen, it sleeps.
I	I extended the length of time before it sleeps, but it still sleeps.
A	If you are in a meeting it sleeps every 5 minutes so…and then the locking thing. Another annoying thing is the keyboard, I just couldn't get used to it. Maybe given enough time I would have eventually.

I	(explaining keyboards)
A	So it becomes a laptop…
I	Do you think it could work in industry? Or are there problems with bringing such technology into somewhere like Airbus?
A	Recording, taking pictures…well I guess it's mainly security. A matter of what is discussed. There are meetings and then there are other meetings where you would use it in a development environment. When you are developing software. It could be of use. But when you're developing a product…like an aircraft it would cause problems.
I	So software development of different to Airbus secure data? You're not discussing the geometry of a wing…?
A	That's right.
I	So it doesn't need to be as secure?
A	That's right.
I	Do you think there's any potential for similar technologies or how would you change it if you were to design your own tablet?
A	I would make it slightly bigger. Battery life is important. Because if it becomes a regular thing you would want to use it, you wouldn't want to be dependent on the battery life.
I	How long is the battery life on that?
A	It's around 4 hours I think.
I	Anything else?
A	Erm…it's responsive enough. That wasn't a problem. (pause) Some of the apps were a bit difficult. There wasn't much help available in the apps, unless you went online.
I	Did you install any extra apps?
A	No.
I	And did you use the internet on it?
A	Yes.
I	Did you just use it in meetings? (not clear here what was said) Did it fit in well with your existing work practices? Your personal work practices and the team work practices?
A	In what sense?
I	So did it feel natural just carrying that around with you? And using it in meetings?
A	Oh no, it didn't at all (laughs).
I	If you were given one of these in your work do you think you could get used to using it? Or do you think you'd rather have a pen and paper or a laptop or something?
A	I would rather have a pen and paper.
I	Have you got anything else to say about it generally?
A	No I think I've pretty much said everything.
I	Would Airbus buy them?
A	No.
I	Would you buy one for yourself?
A	I would wait for it to go down a bit (in price).

A Second Interview-> Pen

A	Oh I thought it was excellent. Especially as compared to the tablet.
I	What is it about it that you prefer.
A	It flows naturally. What you're used to doing. It's not fiddly.
I	I suppose you're used to writing.
A	I'm used to writing. It just enhances what your already doing and what you're already comfortable with. There is no difference between using this and my ordinary pen and paper and the pen has this extra feature of recording the conversation so I think that's just great.
I	Did you use the recording?
A	Yes.
I	What sort of things did you use it for?
A	I used it for meetings with SDC when we had our sprint and I've used it with S [head of Methods and Tools]. [They were] at my desk and explaining how to do the installation so [they] came over and I asked [them] if I could use it. And I have half and hour of this stuff and now I have an idea on how to do a Hudson installation (runs through steps). I recorded [them].
I	Did it change the way you wrote notes?
A	No I tried not to change the way I write. The only thing I do is press the record button when I'm writing.
I	And did you listen back to the notes afterwards.
A	Yes. Did you give me headphones?
I	No I didn't. Sorry I assumed everyone had one at work.
A	I was just worried I hadn't given them back.
I	Did you share the notes with anyone or did you keep them to yourself.
A	No not yet?
I	Do you think you would or is it more of a personal thing?
A	I would share the pdf but not the sound recording.
I	Ok. Any reason for that?
A	Err, I guess it's because these are lengthy conversations and I do not see how listening would be without the context. But yeah it's something, I wonder if that would change it if you send the pdf along with the recording and I guess it would work.
I	You can send it as a pencast pdf when people can click on the text and listen back to it.
A	Yes I didn't try that.
I	So what sort of work did it best support for you? You said you used it in a planned meeting, and then an impromptu meeting with S or was it planned?
A	It was planned.
I	Did you use it any other times or was that the only times you used it?
A	I've used it in a number of meetings. I've not used it in an impromptu meeting anytime, no.
I	How, I think you've already commented on using it, how quick was it to use it.
A	Straight away.

I	And did you go back and use the notes that you'd made to check things.
A	Yes I did. Only last night I was checking on the Hudson because it's something I need to do today so it was very helpful.
I	The audio.
A	Yes on my laptop. Ok now that you mention there was an impromptu when I used this with C so this was when we had, I was explain to [them] a concept and I needed to draw the diagrams for [them] so I did them on this (the book) instead of their book so I could email it to them later. I never emailed C but that was the idea.
I	Did the pen meet your expectations? How did it match your expectations?
A	technically?
I	Yes.
A	yeah it's quite a goo product, it's very clear what you're choosing on the screen, nice, easy to use and the audio quality is quite good. Ah there is one thing, if you switch on the microphone the writing, you get the scratch sound.
I	I get the same thing. Now I have a new tip. I think it's less scratchy. Maybe it's a thicker bit I don't know.
A	Takes lid of pen (struggles).
I	Yeah you see this one's less noisy it's got a thicker tip. You can
A	You do have thicker writing.
I	and also you can buy headphones that you attach to it that have a microphone in the headset so you get the noise from elsewhere. But then you'd have to have the headphones. Erm, so do you think it's got the potential for use at Airbus or you personally. Do you think you can see people using it.
A	I see myself using it. If it's not too expensive I was thinking of buying it for myself.
I	It's 80 pounds.
A	80! The books are alright. You said £15 for 3?
I	4. The pen is expensive yeah. It's gone down £20 since I bought this one so I don't know if they'll keep getting cheaper. So you think £80 is too expensive?
A	For myself yes. If the company provides them…
I	Do you think it's something they would provide?
A	I don't know.
I	Do you think there's any problems using it in Airbus? Do you think people would have problems with the recording?
A	Yes before every meeting I usually announce that I'm going to record it and they don't have a problem. If there's a senior manager presenting something confidential then there might be.
I	Again something I think you've probably already discussed. Does it fit in naturally with your work processes as they were? It didn't interrupt you in any way?
A	No, no way. Erm, actually I am meeting the head or aerodynamic in a 1-2-1 meeting next week, the 23rd, if the pen was available I would have shown it to [them].
I	Well I actually I was going to ask you if you were happy to use it until the

	end of the project?
A	Yeah. Excellent.
I	I'll probably do a quick interview again at the end, to see if there are any differences.
A	I think it is a good idea. [They are] head of Airbus Aerodynamics, and [they have] 1-2-1 meetings with ordinary employees. And I have one next week.
I	Erm, I mean, prior to me saying that would you have liked to have used the pen. Well you say you'd buy it yourself so you'd quite happily use it in work?
A	Yes.
I	Do you think that the way it works would need to be changed in any way, or would you like it to be changed, any features that would be different.
A	Yes I ran out of battery one time that I wanted to use it.
I	Yes C had that, I've never had that.
A	The life is decent enough, but perhaps if there is some feature where you can change the battery, or a booster(?) button, I don't know.
I	And anything to do with how you upload it or anything else, I mean you've already mentioned the scratching of the pen.
A	The software on the computer there are at least 4 clicks before you can actually access your data. So there is, it tells you about registering, it tells you about updates, it tells you about connecting to the internet and you click answer, answer, answer. I'm not very sure how safe it is to register your pen. Would it transfer your data to somewhere on the internet. I really don't know.
I	I don't know, I didn't register mine for that reason. In general do you have issues with trusting the pen? Is that your only worry. Trusting the data on it.
A	I would prefer it not to connect to the internet at all.
I	But what if you wanted to share it with other people?
A	There should be an option where you click the pages that you want to send. Like you have the record buttons. But there should be no automated sharing of data at all.
I	Ok. Is that a personal thing or for Airbus.
A	I think for Airbus because you never know if your data goes on the internet who might be hacking it so you want it to stay on your computer.
I	How do you feel the 2 devices compare, the tablet on the pen? Any features? Which are your favourite or least favourite features across them?
A	(pause) I quite like the fact that when you're recording it highlights the whole thing in green so you can get back to the conversation very easily so you what…….was very handy. Recording is easy, just press a button, very good.
I	Compared to the tablet?
A	The tablet, it's too fussy. It's not very, it's too awkward to use?
I	Do you think you would have got used to the tablet over time?
A	I don't think so.
I	Did you use any other features of the pen like the calculator, or the piano!

A	No. I will try that. It's at the end…
I	Yes on both sides.
A	(checks out calculator).
I	And are there any additional features that you'd like it to have? Have I already asked that?
A	Erm, (long pause). I can't think of anything else to be honest.
I	Ok. Erm, so overall how do you think it added to your existing work? What was the main benefits it provided?
A	Erm, ok it makes capturing the minutes easier because you are recording it. Sharing of data. I remember C sent me for their report, [they] used some drawings they looked as if they came from the pen.
I	They probably did, yes?
I	You liked receiving that from the pen.
A	Yes it was quite good.
I	It's interesting to see both sides of the use. You using it yourself and gaining from other people using it.
A	Yes. Yesterday actually I didn't have my laptop but there was an issue with some basic trigonometry with the SDC employee and [they] sent me a picture which I think [they] took it from their mobile phone and [they] emailed it to me, ok this is what I get. And I wanted to send [them] some drawing and I thought I'd use the pen but I had no way of actually transferring the data from the pen to my laptop.
I	So it would have been good to do it instantly.
A	Yes that would be a feature, it it was wireless it would be fantastic.
I	I think you might be able to do that on other ones. This is the cheap one. So the ability to instantly.
A	Yes so say somehow you could have a send button here connected to that, you could send that page directly to that account.
I	With more advanced use of it, there's certain things that you can write, like email. I think you start it by writing a line both ways, then you write email. So when you plug it into your laptop it will automatically send it to email. But you have to plug it in. But if it had wireless, rather than a button you could just write it down, to such and such address, it would do it automatically.
A	What about syncing it with your laptop, say it's wireless right, it knows the page number.
I	Yes it does.
A	You say connect to button, or somewhere here you press, it will connect to your laptop automatically and you can see it on your screen. And at the end you press send.
I	I like that idea. And did you carry it round with you all the time?
A	When I go to SDC it stays with my laptop.
I	And it was ok to carry around.
A	Yes it's small.
I	Okay I think I've covered most things unless you've got anything else you wanted to add.
A	No I'm quite happy with the product and if it were cheaper I would buy it.
I	Maybe it will get cheaper.

A Interview Three -> Pen

I	Did you manage to show the pen to that person?
A	I don't know, it's one disaster after another. Last time [they] cancelled it and this morning [their] plane was delayed because of the fog. So [they] had to go to Broughton instead of Filton. So [they] had to cancel all [their] appointments.
I	Is it cancelled now so you won't get to see [them]?
A	No. That's it.
I	(mentioning possibility of keeping pen for longer)
A	Now there is no date. Last time [they] postponed it but now [they] came but didn't get to see everyone. It's a shame as it would have been a good feedback.
I	That's ok. Well it's still interesting to get your opinions on it so…this is just to follow up on what I asked before really. Just to see if you've had any continued use of it, any changes in your opinion and things like that.
A	Did I mention the battery life last time?
I	You may have done but say it again anyway.
A	I still think that's one of the problems.
I	I'm wondering if it's a problem with that pen cos mine has never runout but maybe I don't use it for long enough.
A	The meeting lasts 2 maybe 3 hours…
I	And if you're recording for the entire time…so not long enough for a 2 – 3 hour meeting. Yeah my meetings are more like half an hour. So have you carried on using it since I last spoke to you?
A	I've used it a couple of times again with our sub-contractors but I cannot use it…it's difficult for me to use when in a telecon.
I	Yes I've tried that once and you only get what you say.
A	So I guess that's the reason why I mainly use it with our sub-contractors as we have face-to-face, whereas anything else project partners are on the phone.
I	And have you used it in any different ways? Or is it just meeting minutes?
A	Just meeting minutes….jotting things down.
I	Have you shared any of those? I think last time I spoke to you you had something that you were going to share with C?
A	No I haven't shared it.
I	Have you shared anything with it?
A	Err, no.
I	But do you still think that you would do that?
A	Oh yes.
I	And has your opinion of it changed in any way?
A	No. I still think it has potential. But another problem is that I cannot connect it to my official laptop.
I	Yes I thought that might be a problem. So you've been connecting it to your personal laptop?
A	Yes. (ripping out pages from notebook for A to keep).
I	So if you had it permanently do you think that would affect the way you used it?

A	Yes.
I	How?
A	Err, first of all I wouldn't have the other (note) book with me. I wouldn't just have this one.
I	You'd just take that book. That would be your only one.
A	(unclear)
I	So you don't think you'd use it any more or less?
A	I would still use it as an ordinary pen but I would be able to do extra things like record (unclear)
I	Can you imagine any other uses for it beyond meeting minutes and things like that?
A	Erm well recorder is one. You could you know when you're writing, everything you write, I dunno there is a tiny camera, you could use that as a scanner.
I	To be able to take a photo of something as well.
A	Yes. Or scan a barcode for instance. (unclear)
I	Because it's got the display on it. It's not internet connected but it could be. Before you said you'd like it to automatically sync.
A	Yes it should do that. Connected to the cloud. Oh that would be very good actually. Upload everything you write to a cloud. So you're basically writing in a virtual notebook. So if you lose your notebook…it's being backed up continuously.
I	Yes I like having that. I don't often share it or listen back, but I know if I lose my notepad it's still there in my pen.
A	And if you lose your pen it's still…somewhere.
I	Yes on your laptop or your pen or notebook. (pause) Do you think you'd need to change your work practices in any way to fit the pen in permanently?
A	No that's the beauty of this thing. You don't have to change anything. You just do it.
I	Do you think you could be flexible with the use of the pen for other things? It's got the calculator in it and all that stuff. Is there anything else you might…I dunno that's probably a bit of an abstract question.
A	We we've already said scanner. With the scanner sometimes when you're reading something and you want to record the equation…perhaps it has a mode (unclear).
I	And do you think it's a useful technology for people to have in the workplace? Like if loads of people had it do you think it would make a difference.
A	It would make things more efficient.
I	Why do you think that is?
A	Cos of sharing of data. Everything would be in electronic data format automatically.
I	But as a personal thing. Instead of sharing you seem to keep it for yourself so you go to a meeting and people say things and you can listen back? Ok.

A	(Nods)
I	It's quite a different tool to what you'd normally be provided with in the workplace. Do you think it's a useful thing for a company to provide? It's not a particular application for anything, it's just sort of a general tool.
A	Not really. I know in some companies they do give you handheld palmtops. It's not at that level but I don't think it's anything new really.
I	Do you think people might bring in their own ones if they had them? Would you, if you had one at home, bring it into work?
A	Yes I would.
I	And do you think Airbus would be ok with that?
A	Hmmm I think you'd need to convince the management level. Cos it's a hazard. It's a security….
I	So if you were going to show this to the head of aero, and if you really wanted it taken up by Airbus. What do you think you'd have to do to get it in use? Who would you have to talk to?
A	I'd escalate it to head of department to show them how good it is and what I have already experienced. How it would help them. Have a small presentation like…
I	Do you think you would do that? Is that the kind of thing you would consider doing?
A	Yes I would.
I	Do you have anything else to add?
A	I wish I had had time to show it to the other guys (in the group).
	(off topic)
A	Well if the price drops I'll buy one for myself.

C Interview One -> Pen

C	I used it as a standard notebook. Recording. The first time I used it I ran out of battery. In the middle of the meeting. But anyway…here is a list of what we did in the meeting. … And then I found it quite useful an assignment to build a conceptual model of what is going on in this project. I used it to build a conceptual model and a rich picture. I could draw it, then download it as a pdf, upload it as a pdf on my laptop and then put it in the assignment as a pdf.
I	So did you share that with people?
C	Er that has been submitted already.
I	So that's for your university work?
C	Yes and er, (flicks through notebook), I was supposed to share this…but eventually I didn't, I just explained to…to this person how a particular bit of code is structure. I was supposed to share it with [them] as a pdf but there was no (need?) at the end.
I	Where they the 2 times you used the pen then? Did you use it any other times?
C	Yes, er, I recorded the meeting but I didn't listen to it after the meeting. But over the last two weeks I have been at university. But using it I realized that it could be really useful for example I attended a lecture rather for professional life. You see here, people don't record meetings. I

	mean they could use a normal recording device, but they don't do it. I think mostly because they don't have enough time to listen to the recording after meetings and things like that. I think it's more suitable for lectures and students than professionals.
I	Did you record any audio when you were doing your assignment?
C	No just the camera.
I	And did you find it easy to learn how to use it?
C	It took me a bit of time installing the software. First you have to install the software and then plug the pen in. I missed that point so that caused me some problems But I eventually sorted it out. But it took me one hour.
I	When you recorded the meetings you said you didn't go back and listen to it…
C	No
I	So it didn't help you with remembering things or anything like that?
C	Well to say it probably…(unclear)..I used the recording capability in this case…and I was talking with A and [they were] saying something and I started recording and I think I might use it in the future.
I	You might go back and listen to it. Ok. So in a meeting is it nice to know that you've got the pen there? Did it change the way you took notes?
C	Yes because, err, personally I don't write very much during the meeting so as I understand, if you write something then it starts recording and if you want to..if you point then pen and that point you have twenty minutes or recording. SO I think the recording capability is useful if you write a lot. If you just write a few words during a meeting then you have a word here and 20 minutes of conversation and another word here and another twenty minutes. In that case I don't find it very useful. But for people that write a lot.. I had a chat with [EngD student]. Do you know [student].
I	No
C	[They're] an EngD. [They] write a lot and [they] thinks it would be really useful. A bit expensive but..
I	Did you get any other reactions to the pen?
C	Yes, curiosity, a lot of curiosity. I used the recording capability to show that if you point at a particular part of the page you can listen to what people were saying.
I	Were they people at SDC or people here?
C	At SDC.
I	Did they seem to like the idea of it?
C	Yes.
I	Did it meet your expectations? Did you feel it was better or worse than you expected?
C	I think it was better than I expected. In this case I found it quite useful. But I'd say that when you upload the pdf…there was something written down here…that if you wanted to upload a picture to the assignment you'd have to cut it off (referring to the text that appears at the bottom of the pdf). It says click here of you don't want to see this writing but you can't click.
I	Would you use it again in the future if you had the opportunity to get one

	yourself, if it was cheaper?
C	If it was cheaper, yes. Probably it will be cheaper in the future. …I had a look on Amazon.
I	Do you think it's got potential in the workplace?
C	I think it could have potential. I was thinking to use it in this case, then probably two week is not enough. In one month I would probably have had the occasion to share. I'm a bit concerned about the recording capability as well…I don't think a professional, as I said before, would use the recording, to go back and listen to what was said during the meeting.
I	You don't think people would do that? Or the quality is not good enough.
C	No it's not about the quality. As I said before I don't think professionals would have time to listen. And there's some other issues with confidentiality. What is said here is confidential so you're not supposed to either (unclear)..
I	Did it fit in with your existing work?
C	yes but in the meeting as I said I don't write very much so I forced myself to write more. I thin another issue that may arise is that people don't know that this is recording…so probably you should tell people that…but I think it's clear enough.
I	(I always tell people) Do you think that there are any other problems with using it in this context?
C	Well confidentiality is a problem. Other than that I don't see any other.
I	Did you take the pen with you a lot? Or just at certain times?
C	Yeah at some times I preferred doing a sketch using a normal note book. And then I realize (unclear) using the notebook in a meeting and then I started using the note with the recording for other purposes. (r(referring to notes) This was a sprint meeting. I was using it for some calculation. (Referring to notes) This was a sprint meeting. I was using it for some calculation.
I	Did you see it as something you would use for yourself or that you would use to share things?
C	I would say both. I would say it's a bit annoying having the software and then plug the pen in. That is the most annoying part.
I	Is there anything that you'd like to say about your experiences with it?
C	No.

C Interview Two -> Xoom

I	Is there anything that you'd like to say about your experiences with it?
C	No.
I	So how did you find the xoom.
C	It's useless.
I	Useless?
C	Yes is the definition.
I	What's useless about it.
C	Well I was using it during the meeting to take notes but I found the keyboard quite awkward. I mean probably if you use it but I'm not a touch screen devices uses, I don't have any touchscreen devices. If you

	are a touchscreen devices user then you may find the keyboard much easier to use. But I find it awkward, even the drawing. In a meeting I don't think it's useful because erm it can be the same as in a meeting drawing a picture on your notebook. There's no reason when there's whiteboard available. Probably I think if there was a device, a screen compatible with this then people then you can draw and people can see it on the screen, that would probably be useful but other than that, yeah. And err you know I use the recording capability as well and I didn't listen.
I	You didn't listen to it?
C	As with the pen.
I	So how did you use it? Did you take it to meetings?
C	Yes I took it to meetings but it was just there (gestures at tablet on table).
I	You didn't use it?
C	Recording…
I	What were the main apps that you used then.
C	I can't remember the name. Now the button is down (tablet turned off). Can you remind me, there was one where you had to pay for it and one that you can record. It's called 2 can?
I	I installed quite a lot so I can't remember. (retrieves tablet). Any of those?
C	Think it's audio… that is free…
I	I might have paid for the one on that one (tablet). Has it crashed (tablet screen has gone dark).
C	No the batteries down. Can I see…
I	No.
C	That's not it? The recording button was at the bottom.
I	(Scans through apps.)
C	Anyway the principle was the same, you can type and record.
I	Erm, did you use it to share anything with anyone?
C	No.
I	Okay. Do you think you would if you had it for longer?
C	Probably yes.
I	What sort of way might you use it to share things?
C	Well I would say using it as a laptop, sharing pdf, writing email.
I	Yep.
C	But I probably, in a working environment I usually use the Airbus account or SDC one but with this I can't access….
I	You can't access them, right… Did you use any of your own accounts on it?
C	I only tried to access my gmail account.
I	Erm, so you think if you could access your Airbus account on that, I know it's entirely hypothetical, but if you could you would use it?
C	Yes.
I	Or your SDC account.
C	But the problem is if you think you can access your Airbus account from this then you can also access the Airbus account from the desktop as well and in that case I would use the desktop. I'm talking about in a working environment. You could use it for entertainment or social networks or seeing videos that probably. It is a good device for entertainment rather

	than a working environment.
I	Did you take it to uni when you were at uni?
C	No.
I	Erm, how did you find learning to use it? Was it easy to use or did it take time.
C	Well, er, browsing, web browsing was quite straight forward and then I used that for….(it stopped working yesterday) yesterday. There was an advertisement coming out. I don't know why.
I	Maybe I need to top up the 3g thing. Did you plug it into your laptop at all?
C	No.
I	Did you share anything with your laptop? You just kept it as it was? Ok. How did it meet your expectations. What were your expectations I suppose?
C	(pause) Well I think I didn't really have expectations because personally I'm not, I don't use either recording device or I don't take notes. I do it with my notebook so. You see why I have trouble with using tablet.
I	So how did it, well I suppose if you didn't have any expectations it can't really match it. Erm, what does you think it has any potential uses beyond what you used it for?
C	Well errr, I have to say in for example in our cases where you had to show diagrams, pictures, rich picture, this is not good because it is too small.
I	It's too small? Ok. So you can't see it being used for anything else? Did you take photos to share?
C	I didn't take photos but I think it could be used to take photos at the end of each meeting. For example Craig takes photos of the whiteboard at the end of each meeting. It can be done with this I suppose.
I	Erm, how did it fit in with your existing work practices?
C	Err, I would say it didn't fit in that way. Well you have to run simulation on my laptop and I don't think you can run a simulation on this. Something about Eclipse. But if you could the scale is too small.
I	So you don't see it as an additional thing to a laptop, you see it as a replacement?
C	No. I probably if I could access my Airbus account then I would send email, browsing.
I	How would you compare the tablet and the pen?
C	Well I found the pen more useful?
I	Why do you think that is?
C	I use it to draw a rich picture and for that it was useful. If I had to draw a rich picture with this (points at Xoom) it is much more difficult using your finger to draw. To draw a rich picture in detail.
I	What, if you could change it to make it useful what would you do with it?
C	I would probably add a keyboard but then it's a laptop!
I	Anything else, any software, I suppose you've already said to have the account on it.
C	It's heavy.
I	It's heavy. This (Galaxy) is light.
C	Ahhh if you want to switch it on the button behind is hard to find. It took

	me some time to understand how the switch was done. I'm talking about hours.
I	I did the same thing. If you have it lying on the table…. I extended the switch off time.
C	I have a Kindle and I use that to read pdf because you don't get your eyes tired. So I prefer using that rather than this for reading pdf.
I	So you use your kindle quite a lot then?
C	Yes.
I	For work?
C	No mostly to read paper. When I have a paper I'm not sure about it, but if you find it interesting you can print it out.
I	Did you have any issues with trusting the applications or anything with your data. Would you be happy to put your data on all the apps that I installed on it?
C	Yeah why not.
I	Do you think Airbus would be alright with that.
C	You mean?
I	The security of the data on it.
C	Well as I said, confidentiality issues with recording and it sometimes the tools that I use for simulation is. So other than recording but I think that with the pen people might not know that it is a recording device and with this people may not be aware that I'm recording.
I	I don't think I have any other questions. Unless you have something else to add.
C	Well I'm sorry if I don't have information to give to you. Other than it's not useful, knowing that some people think that these things are useful.
I	I want to find anything out I'm not hoping everyone thinks it's great. If people think it's rubbish it's interesting to me, in fact slightly more interesting.

C Interview Three -> Xoom

I	So did you use it?
C	Let me show you. So I prefer taking notes on paper. Simply because what if you want to draw a diagram like this…quickly. Is there any way you can do it quickly here?
I	Is there? Some of the apps you can draw on. Some you can't. I think you can draw on this one can't you? Isn't that a pencil.
C	Yes but it's not as accurate as errr…
I	It's not as accurate. Ok.
C	And also it was causing me some problems….switching to…and I found myself trying to type and it was too small…
I	So the changing of the mode. If you have a pen you can write and draw…on that you have to change?
C	Yes. Probably what I would have liked….something that would be nice….would recognize what you write.
I	Text recognition. Like the pen does?
C	Yes. And also I tried to open a pdf…but I couldn't see anything on the

	screen.
I	Oh that's odd.
C	I mean the pdf was open but I couldn't read the text. I could only see a few points. (unclear) I use bullet points when I take notes. Here what I've done it writing a number…Probably there is a way to (do it). I couldn't find a way to write down bullet points. And also if you want to draw symbols…again… (unclear).
I	Would it be easier if you had a pen? A stylus?
C	Yes.
	(discussion about the stylus that was bought but wasn't very good)
C	I tried to share, to send a document to my main email account. But there is no internet connection.
I	Oh! It must have run out?
C	Yes. I'm surprised because I used it…
I	Oh it might have been time. If you had let me know I would have topped it up.
C	Yes I used the internet for maybe 10, 15 minutes.
I	Yes it expires at the end of the month and you have to redo it I guess. So the internet didn't work. That's my own fault. Sorry.
C	I was just sharing because I was curious to know if I could open it on my desktop. Probably there was no need to share.
I	So you had no other need to share it with anyone. Ok.
C	And again for this type of project if you want to share a file you what you do now is (unclear) in Python and send the file to A or….
I	So you would want to send a python file, not something else.
C	Yes there's no point sending a Python evaluation file, a text file to…. (Pause)
I	So has your opinion of it changed at all?
C	No. It's good for entertainment or if you are at university or you want to access your account.
I	Is there anything you think you could use it for at work?
C	Er definitely not. The feature I got here, this feature on my mobile now…I just use my phone. I can read my gmail account, get google doc, maps, can take pictures. So I don't see any reason why I should get one of these.
I	So you use your phone for work? What's your opinion on bringing your own devices like phones into the workplace? Is that something you are able to do at Airbus?
C	I'm not using it for work. I use my gmail account for work actually, yes.
I	Have you ever done something like take a photo on your phone and use it for work?
C	Yes. I've done it at university. Taking a photo of drawing on a whiteboard and sharing it by gmail.
I	And could you see yourself doing something like that here or is that not allowed?
C	Well I've seen people here doing it.
I	Because sometimes people have devices at home that are better than what they have at work. So people could bring in their own things like tablets and use them.

C	Yep. I've seen [SDC dev] doing it.
I	What [have they] got a phone or a tablet or something?
C	Yes I remember when we were doing the Sprint planning every week. [They were] taking a photo of the whiteboard at the end of each meeting and (unclear) was asking me to share.
I	And that was for this project?
C	Yes.
I	This might be rather an abstract question. But I was looking for lightweight or flexible tools that you can use for anything. It's not got a dedicated purpose. What's your opinion on that for supporting this kind of work? What's its place in the software development process? Do you like the idea that you've got something quite flexible and not a specific tool, like not a specific collaborative portal that's specifically for this team or anything?
C	Sorry I didn't get the question.
I	So do you feel that the use of devices like this (the pen) and the tablet, that are quite multi-purpose..you can use them for lots of different work, rather than specific tool that had been developed for you guys to do your work with. Which is preferable to you?
C	You mean this tool as opposed to…
I	A tool that had been designed to support your exact task. It might be a bit of a difficult question…
C	So there are tools that I have already for this project, on my desktop. But they are all here in my desktop (unclear….)
I	So do you have tools like RedMine that are quite specific to the task that you are doing?
C	They're using redmine for
I	But do you like the idea of having a tool that's like a pen or notepad where you're not as constrained in the way that you use it? Is it a case of having both. Quite specific tools for what you're doing with other things like phones to support…
C	I think we need anything specific (unclear), this should be personal. The company should make available this kind of pen to share…
I	They shouldn't make everyone have one?
C	Yes probably. So you should have to bring your own pen from home but then you'd have confidentiality issues.
I	So you'd rather they give you them or you bring your own in?
C	The company should provide this kind of tool.
I	So the company should provide it rather than having to bring your own in.
C	Then it's not so great using a (Xoom?) to share this data. One doesn't want to buy an expensive…It was a value for the project taking pictures of the whiteboard…so why…
I	Aren't they provided…
C	Yes.
I	So you think there is a role for that kind of tool. Do you think that is something that the company should provide as well as like the software that they give you?

C	Yes.
I	And if the company did give out pens like this do you think that people would have to change their work practices much or not? Like policies and processes and things?
C	(really long pause) Well I don't know with the policy of the company. Avoid people using it for personal purpose.
I	If you were given the tablet for work do you think you would use it?
C	No not to do this kind of work.
I	But if you were given the pen?
C	Yes I would use that probably.